Montana Connectivity Project

A Statewide Analysis

Montana Fish, Wildlife and Parks

August 2011

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In partnership with the Wildlife Conservation Society and the National Fish and Wildlife Foundation

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This document serves as the final report for the grant received from the Wildlife Conservation Society. It will be updated following the completion of the species aggregation, integration into the Crucial Areas Planning System, inclusion of uses and limitations and completion of the Large Landscape Block Analysis and Landscape Network.

Acknowledgements

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Connectivity Charter Signators: Dave Risley, Montana Fish, Wildlife and Parks (MFWP) Fish and Wildlife Administrator; Ken McDonald, MFWP Wildlife Bureau Chief; and T.O. Smith, MFWP Strategic Planning and Data Services Bureau Chief.

Core Connectivity Team: Jeff Herbert, MFWP Wildlife Assistant Bureau Chief, Janet Hess-Herbert (Data Services Supervisor), Adam Messer (Connectivity Technical Lead and Staff Supervisor), Joy Ritter (GIS Analyst), John DiBari (GIS Analyst) and Brent Brock (GIS Analyst).

Connectivity Technical Advisory Committee: MFWP staff: Jeff Herbert, Jim Williams, Vickie Edwards, Kurt Alt, Craig Fager, Allison Begley, Kelvin Johnson and John Ensign; Keith Aune (WCS).

Contributions from other individuals, groups and committees are presented in Appendix A.

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Implementation Update January 2014

The connectivity project was started following the initial work on the Crucial Areas Planning System (CAPS), Montana's Crucial Habitat Assessment Tool (CHAT). As one of the first states to begin working on the Western Governors Association's (WGA) Crucial Habitat and Corridors Initiative, Montana began examining species and habitat connectivity at the landscape level in 2008. As documented in the following Executive Summary and documentation, work was largely completed in 2011. Since that time, continual improvement and efforts have been made by the western states participating in expanding the work of the pilot states to the west-wide CHAT system. That work followed the same trend as Montana's efforts which eventually reflected a broad level evaluation of connectivity as a function of the landscape over the focus on individual species.

Much of the following documentation outlines the project process and analytical methodology based upon the approach of evaluating connectivity at the species level. Generally the species level process involved identifying core habitat blocks and the most likely pathways of movement between those blocks using habitat suitability models. Most of these models were developed during the initial work on CAPS. The primary limitation with these models is that many species lack sufficient data to inform modeling efforts, and little biological experience exists to evaluate them. These limitations are more pronounced when examining lesser known migration and movement behaviors. While some species models seemed reasonable based upon biologist review, they are difficult to interpret without the biological understanding of the species, movement behavior and model assumption. Thus the recommendation from the FWP wildlife management staff was that species specific data be an internal product to be used by FWP biologists when determined to be beneficial to specific conservation efforts.

Broad scale models of landscape connectivity based upon general habitat characteristics are the publicly available final products from the connectivity project. These large landscape block ecotype models (Section 3.3.3) are provided in the CAPS application for All General habitat, Alpine, Grass/Shrub, Forest Generalist and Forest Specialist classifications. These models selected habitats that could be grouped into the classifications and then evaluated the level of anthropogenic disturbance to derive core habitat blocks. It is assumed species within these classifications select for suitable habitats and avoid anthropogenic disturbance as well when moving between core blocks as a measure of connectivity. These models eliminate the requirement to model specific species behaviors in favor of the assumption that native habitats within an ecotype class are selected for and habitats not in the class, or any habitats that have been disturbed, are not selected for. These models are much simpler, more useful and understandable in the context of the conservation discussion.

Regardless of the final results presented, the effort to understand and explore connectivity as a conservation priority is important and will continue. The connectivity project documentation is provided so that other entities exploring the connectivity discussion can learn from these efforts and build upon what has been done to date.

Executive Summary

Conserving and maintaining terrestrial and aquatic habitat connectivity is essential for a variety of fish and wildlife species' life histories, including movements to food or shelter, reproduction requirements, seasonal movements, and/or dispersal to maintain healthy populations. In addition, access to suitable habitat in response to changing weather patterns and shifts in vegetation communities will help ensure the potential long-term viability of wildlife populations.

In November 2008, Montana Fish, Wildlife and Parks (MFWP) launched a Crucial Areas and Connectivity Assessment (Assessment), aimed at producing a planning and information tool. Referred to as the Crucial Areas Planning System (CAPS), it is designed to assist in assessing fish and wildlife values during the early planning stages of conservation and development projects. In addition, MFWP focused their efforts on the integration of final products with the Western Governors' Association's Wildlife Corridor Initiative.

The Connectivity Project of MFWP's Assessment was intended to provide the greatest habitat conservation benefit to support the greatest number of species. The goal was to identify priority geographic areas in order to maintain wildlife connectivity between important habitats in Montana. There were three phases to the Connectivity Project beginning in the fall of 2008.

Phase I developed a process to select focal species to be used in the Connectivity Project. Phase I work was conducted by the Connectivity Working Group (CWG), a multi-disciplinary team made up of agency staff, NGO representatives, state and federal government agencies and university staff.

The initial list of species consisted of Montana Species of Concern with a State Rank of S1-S3 and species identified by NatureServe with a Global Rank of G1 and G2; species having greater than 10% of their breeding range in Montana; species chosen for their socioeconomic value; and species sensitive to habitat connectivity loss that were not already included. These species were placed in a matrix that was sent to species experts for characterization of ecological processes and vulnerability to threats. In order to assure that connectivity between all ecotypes were included, we used the general ecological associations developed by NatureServe with a geographic component that distinguished western Montana ecotypes from eastern Montana ecotypes. For each ecotype combination, species were sorted first by their process score (total number of connectivity processes they depend upon) and then by their total threat score (their vulnerability to loss of those processes). Each species was then ranked based on these two scores.

The top five ranked species for each primary ecotype combination were selected as candidate focal species. After a final review by the CWG, a final focal species list was designated with the assumptions that:

- satisfying the connectivity needs of these species will satisfy the connectivity needs of most vertebrate species in Montana;
- there is redundancy in the list relative to connectivity on the landscape which will become apparent as mapping proceeds;

- every effort will be made to model/map connectivity for all species, even where data is limited;
- it may be necessary to map species in separate groups based on scale and
- the list will be adjusted in the future as more information becomes available and as conditions in Montana change.

Due to their unique connectivity needs, semi-aquatic species were identified differently than terrestrial mammals and amphibians. The initial process assigned each species a watershed rather than an ecoregion. Processes and threats were then scored and summed by the same approach used for the terrestrial species. The top ranked species for each watershed were selected as the candidate semi-aquatic focal species.

Bird species also have unique connectivity needs and thus were selected by avian experts in the state through a separate process. The initial list included all birds commonly occurring in Montana and was revised several times to develop the final list. Habitat and potential threats were associated with all species on the list to determine if there were threats to connectivity that were not captured.

Mammals	**Birds**	**Semi-Aquatics Guild**	**Raptor Guild**
Black Bear	Baird's Sparrow	Beaver	Ferruginous Hawk
Black-tailed Prairie Dog	Black Rosy-Finch	Northern River Otter	Rough-legged Hawk
Elk	Cassin's Finch	Spiny Soft-shelled Turtle	Swainson's Hawk
Grizzly Bear	Clark's Nutcracker	**Waterbird Guild**	**Shorebird Guild**
Lynx	Ferruginous Hawk	American White Pelican	Long-billed Curlew
Moose	Greater Sage-grouse	Black Tern	Long-billed
Mountain Lion	Long-billed Curlew	Common Loon	Dowitcher
Mule Deer	Mountain Plover	Common Tern	Mountain Plover
Pronghorn Antelope	Piping Plover	Franklin's Gull	Piping Plover
Pygmy Rabbit	Rufous Hummingbird	Northern Pintail	
Swift Fox	Trumpeter Swan	Trumpeter Swan	
Townsend's Big-eared Bat	**Amphibian**	Tundra Swan	
Wolverine	Northern Leopard Frog	Wilson's Phalarope	

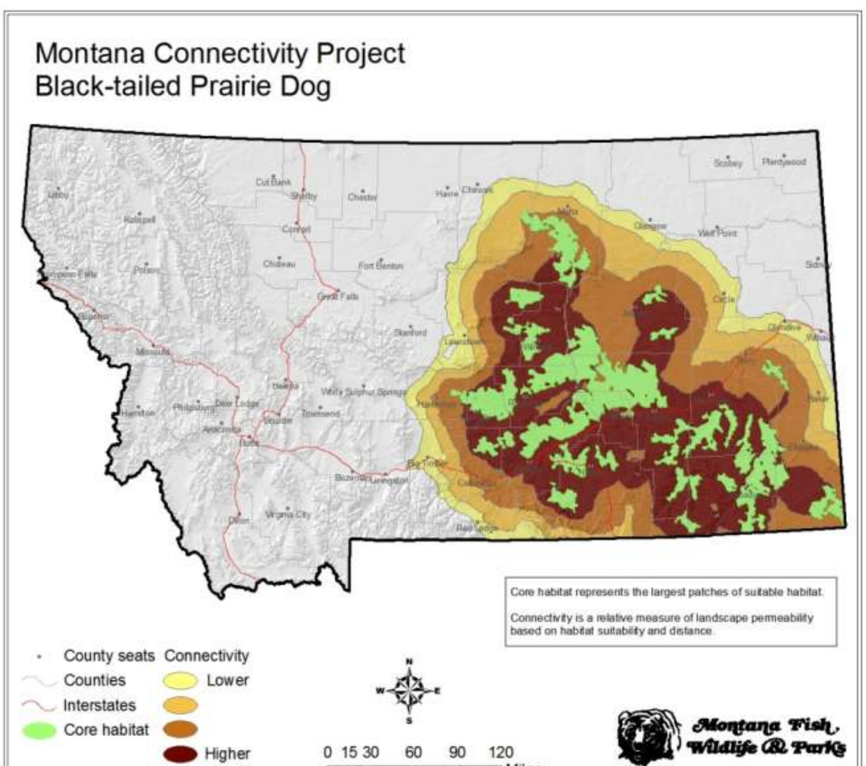
Species/Species Guilds included in the Montana Connectivity Project – Color coded by habitat type: Forest Specialist; Forest Generalist; Grassland/Shrub; Shrub-steppe; Riparian/Wetland; Alpine)

Phase II began in November 2009 supported by grants from the Wildlife Conservation Society (WCS) with a match provided by a grant from the National Fish and Wildlife Foundation. A project charter was developed and endorsed by MFWP's Fish and Wildlife Division. The goals of the Project Charter included: 1) Develop wildlife connectivity layers that identify wildlife corridors and linkage zones for selected focal species; 2) Identify effective scales for source data and display purposes; 3) Create definitions for four categories ranking connectivity and rank each linkage; 4) Create management recommendations for corridors and linkage zones as appropriate; and 5) Integrate resulting connectivity layer(s) into CAPS. Goal 1 was completed in Phase II.

For the purpose of this analysis, connectivity was operationally defined as *a process-oriented property of a landscape that permits movement of organisms.* Such movement may help to maintain and/or increase population persistence and resiliency, species and genetic diversity, and ecosystem processes, including the interchange of genetic information. The connectivity analysis result for a species may be one of several types: linkages, stepping stones and patches/connectivity.

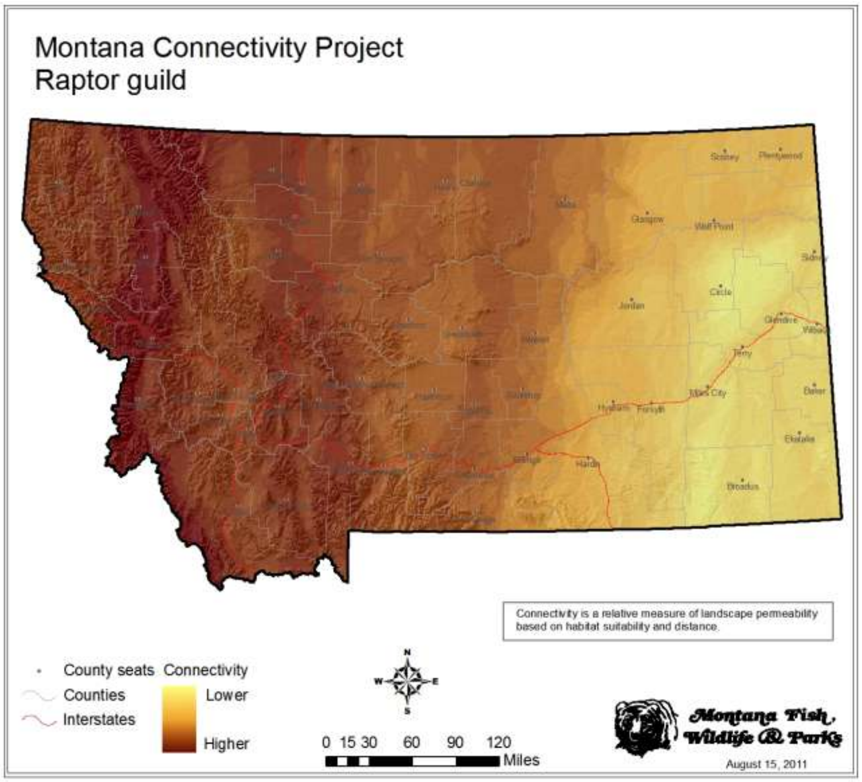
The approach for building connectivity layers followed the same pattern for all focal species.. Variability in the specific parameters used was dependent upon the species or species group. In general, mapping habitat connectivity for species consisted of identifying core habitat patches, generating a representation of cost for the movement of species between those core habitat patches, and modeling the connectivity between these patches to obtain a representation of the permeability of the landscape. We employed three general approaches to accommodate the different methods used to model a species, a guild of species, and a species using landscape blocks.

Species specific models were used when there was an existing model of habitat suitability for the species, represented through MaxEnt models. MaxEnt is a machine learning technique that uses presence-only data to develop a niche-based model to predict a species' realized ecological niche, and by extension, the geographic space the species occupies. These habitat suitability models are based upon characteristics at known locations and background characteristics based upon data from randomly selected pseudo-absence points. Core habitat patches were generated based on areas that exceeded a minimum suitability threshold, combining those areas within a specified perception distance, and then selecting areas that met a minimum breeding and population patch size. We first identified all potential core habitat patches and then selected the 20 largest core habitat patches to run the connectivity analyses.



Black-tailed Prairie Dog Core habitat and the minimum number of permeability slices needed to connect all core habitat.

Species guild models were used to represent suites of prioritized focal species with similar habitat and movement requirements. The guild approach was used to group individual species where ecological requirements and movement behavior did not differ greatly from one species to another. This approach was used for: waterbird, raptor, shorebird and semi-aquatics guilds. This technique followed the same process as individual species by identifying core habitat patches and running connectivity models between them.

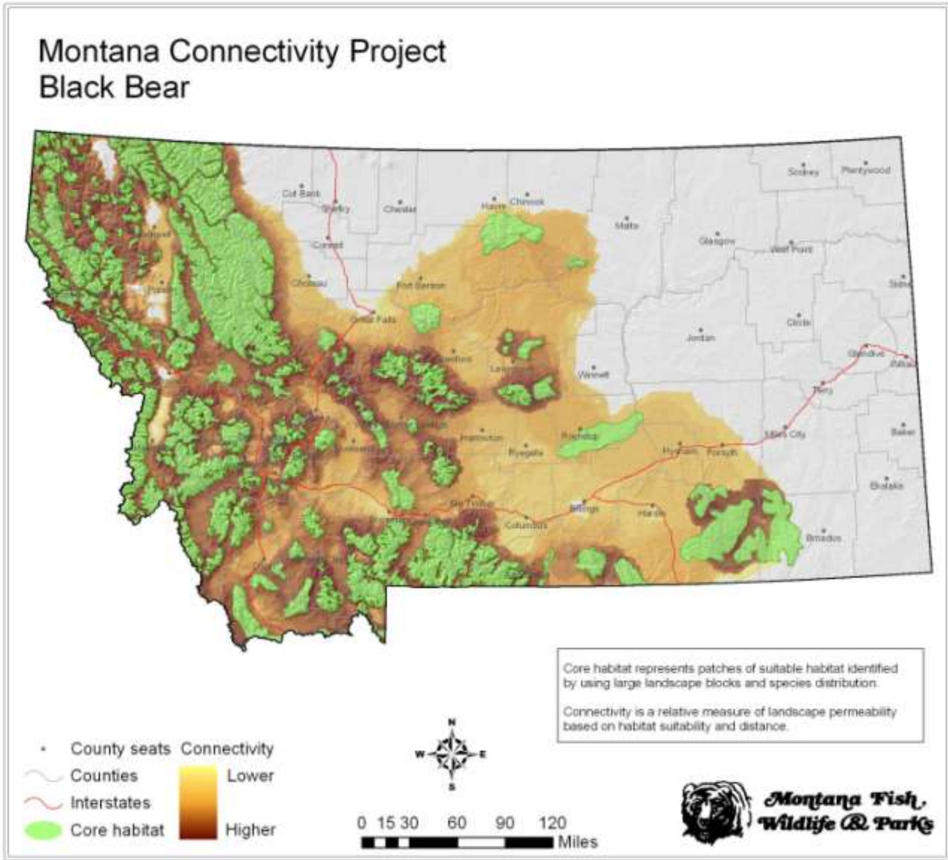


Raptor guild potential range/statewide landscape connectivity.

Landscape Block Species Models were used to identify core habitat patches and movement areas for species without habitat suitability models. This suite of species included terrestrial game and Lynx and Grizzly Bear. Initially, expert knowledge was used to identify movement areas, however the completeness of this information varied and was not comprehensive at a statewide level.

Alternatively, MFWP used a landscape integrity approach to identify large areas of native habitat to serve core habitat patches. This technique identified native habitat, removed areas that had been anthropogenically altered and selected the largest remaining intact areas. We termed these areas “Large Landscape Blocks (LLB)”.

The LLBs were categorized by their general ecotypes including forest, sparse forest, alpine and grassland/shrub. Once a LLB was categorized by ecotype, it was used to represent core habitat patches for species associated with that ecotype. Movement cost were generated using the same habitat and anthropogenic factors that went into the formation of LLBs. Costs varied depending upon the general habitat ecotype being modeled. The resulting connectivity model was developed following the same technique described for the species specific models.



Black Bear core habitat patches and potential range/statewide landscape connectivity.

Connectivity Modeling Technique. We examined three approaches for modeling connectivity which included circuit theory using Circuitscape, graph theory using Funconn, and cost-distance analysis. Considering the number of species to be modeled, our experience and expertise and available data, we ultimately chose cost-distance analysis. As well, we were experienced with this method; models are relatively intuitive to parameterize, explain or evaluate; and the resulting maps are relatively easy to interpret. Because we made no assumptions about the location or strength of linkages and relied on the models to identify areas of potential linkage, we opted for an advanced cost-distance modeling technique that computes multiple pair-wise comparisons of least-cost corridors between core habitat patches. These corridor surfaces were then combined to produce a composite map of linkages between all pair-wise combinations. To automate this process, we developed a suite of tools called “Linkage Assistant” which loops through a list of user-determined core habitat patch combinations and generates pair-wise corridors, a composite linkage layer, and a layer representing percentile slices of the full range of connectivity modeling values. For species specific and guild models we generated 5th percentile slices, whereas we used 1 percent slices for landscape block models.

Data Review and Refinement. All modeling efforts required making assumptions about the response of species to habitat which influenced the resulting core habitat patch delineations and connectivity models. To ensure that the models generated were an adequate representation of on the ground conditions, species experts were asked to provide feedback as the results became available. A "Data Review" mapping application and a Survey Monkey questionnaire were used to collect specific comments.

Phase III began in August 2011 and overlapped with the completion of Phase II. The focus is to explore analyses and display options for the Connectivity Project products, explore composite species layers, and integrate products into the CAPS. Development of additional data, tools and products will occur as necessary.

Interpreting Connectivity Maps. The connectivity maps generated for this project resulted from a modeling exercise that illustrated the lowest cumulative cost-distance associated with an individual of the focal species moving between/among core habitat patches. Output of the connectivity modeling is a raster data set that provides a continuous representation of the lowest cumulative cost-distance values between all core habitat patches analyzed. This raw output, however, is difficult to interpret. To aid in interpretation, the raw data were processed one more time to take the continuously represented data and generate 20 discrete bands, representing 5 % of the values. The resulting pattern shows bands radiating out from core habitat patches. Bands closest to core habitat patches generally represent lower cost-distance values, whereas bands further away from cores represent higher cost-distance values. Bands with the lower cost-distance values can be viewed as being easier to move through as a function of distance and landscape characteristics, representing higher relative landscape permeability for the focal species. These bands *do not* imply frequency of use or indicate how important particular areas might be in terms of connectivity for the focal species. Just because a band or group of bands represents low cost-distance values, that does not mean it is used most often or is the most important. For example, the outer bands may be the most important for facilitating a once in a century dispersal event that connects two isolated populations.

Future Integration and Interpretation. The first three objectives of the Charter to conduct a statewide assessment for 25 species and 4 species guilds for connectivity were accomplished in July 2011. All species, with the exception of wolverine, required developing new models/products because of the scattered geographic nature of existing data.

The remainder of the Montana Connectivity Charter's goals focus on integration of the connectivity products into the operations of local, state and federal government, and private and public entities through a publicly available mapping application and other mapping services.

The first step in this process is to recognize the complexity of what MFWP has created and the need to explore visually simplifying a product(s) to be used as a useful interpretation of connectivity. This approach has been taken in other data types in CAPS because it reduces visual confusion and interpretation when comparing individual species; broadens and expands the number of species and habitats considered during project review; and allows data to be compared with other data layers more easily. In order to address what approach should be taken in creating a composite of connectivity, it is important to understand how our constituents would use the products created. The questions of what is needed and how it will be used will influence the final product development. The evaluation will include addressing the issue of scale (coarse scale/fine scale) and determining what is the appropriate scale for Montana connectivity data, how using finer scale existing connectivity products would be incorporated, and/or provide guidance for their use.

We will initially explore follow a "coarse filter/fine filter" approach. The Large Landscape Blocks will serve as core habitat patches by general habitat type which will serve for the coarse filter. Individual species will then be considered at the fine filter scale.

The final goal in the Charter is to address how connectivity layers will be included in the prioritization process outlined in the Western Governors' Association's Wildlife Council's White Paper, *"Western Regional Wildlife Decision Support System: Definitions and guidance for State Systems"* (WGA 2011). Questions to explore include:

- What do we use to categorize locations on the landscape that are most important for maintaining/improving population connectivity?
    - More use by more species = more value?
    - More permeability= higher value? More resistance= higher value?

These and other questions will be explored over the remainder of 2011, and the report to WCS will be updated at that time. The integration of the final products into CAPS will occur prior to the prioritization process.

Several areas needing improvements were noted during the Montana Connectivity Project. A full list of these are provided in the full document and include: 1) the "edge effects" from modeling solely within the boundaries of Montana; 2) the need to improve Maxent habitat suitability models, which are the foundation to all subsequent analysis; 3) a recognition of lack of knowledge concerning connectivity; 4) a clearer understanding of avian and bat movement and migration behaviors; and 5) a better understanding of species movement through field validation, GPS locations and genetics.

1. BACKGROUND

1.1. Purpose

In November 2008, Montana Fish Wildlife and Parks (MFWP) launched a Crucial Areas and Connectivity Assessment, aimed at producing a planning and information tool to assist local, regional and statewide decision-makers, developers, and MFWP staff in assessing fish and wildlife values during the early planning stages of conservation and development projects. The Assessment also represented MFWP's effort directed at the Western Governors' Association's (WGA) policy framework, adopted in June 2008, to conserve wildlife corridors and crucial habitat throughout the West ((Western Governors Association, 2008). Montana's assessment resulted in the Crucial Areas Planning System (CAPS), launched in April 2010 on the MFWP website (http://fwp.mt.gov). Data layers used in CAPS were also intended to provide information for the update of our Comprehensive Fish and Wildlife Conservation Strategy (CFWCS).

As part of this Assessment, it was recognized that protecting and maintaining terrestrial and aquatic habitat connectivity is essential for a variety of fish and wildlife species' life histories including movements to food or shelter, reproduction requirements, seasonal movements, or dispersal to maintain healthy populations. In addition, movement to suitable habitat in response to climate change and shifting habitats is a part of ensuring the long-term viability of wildlife populations. MFWP, in focusing on the integration of their final products with the WGA initiative, has followed the guidance developed in the Western Governors' Wildlife Council's White Paper, *"Western Regional Wildlife Decision Support System: Definitions and Guidance for State Systems"* (Western Governors Association, 2008). The WGA Definition of Connectivity that guided the development of this process states: _ *"Important wildlife corridors are crucial habitats that provide connectivity over different time scales (including seasonal or longer), among areas used by animal and plant species. Wildlife corridors can exist within unfragmented landscapes or join naturally or artificially fragmented habitats, and serve to maintain or increase essential genetic and demographic connection of populations."*

The Connectivity Project of FWP's Assessment aimed to provide the greatest conservation benefit to the greatest number of species. The goal was to identify priority areas to improve wildlife connectivity between important habitats in our state. An iterative and coordinated approach will be needed to synthesize information and help facilitate development of a habitat connectivity layer.

1.2. Approach Summary

There have been three phases to the Connectivity Project and the work will be reported by those phases.

Phase I began in the fall of 2008 with the task of developing a process/methodology for the selection of the focal species to be used in the Connectivity Assessment. Phase I work was conducted by the Connectivity Working Group (CWG), a multi-disciplinary team made up of agency staff, NGO representatives and university professors. The CWG was in place for almost one year, and was led by outside consultants and MFWP staff. Work was completed in August 2009. This phase was performed with existing resources from MFWP and in-kind services from the CWG. Actual data preparation/assimilation/creation was not possible due to limited capacity. Initial work during Phase I was limited to the aquatic species connectivity that was completed by MFWP and members of the CWG. That product will not be reported here.

Phase II: A grant from the Wildlife Conservation Society (WCS), awarded in November 2009, was the necessary "jump start" to begin connectivity data layer production. Match for the WCS grant was provided by an additional grant from the National Fish and Wildlife Foundation in December 2009. Major tasks during Phase II were to hire necessary staff and redirect existing MFWP Data Services staff; create a project charter that was approved by MFWP Director's office in March, 2010 (Appendix B); create an internal Technical Advisory Committee (TAC) to provide project guidance and oversight; identify species experts, refine the focal species list, gather existing data, and explore a variety of methodologies and approaches; and create a data layer(s) for each focal species. Phase II ends with the completion of this initial document to provide to the WCS to complete requirements of the grant.

Phase III will be ongoing and overlaps with Phase II, beginning in August 2011. The focus of Phase III will be to explore analysis and display options for the Connectivity products through input from members of the original CWG, MFWP staff, species experts, state agency and federal land management agency staff and further data and tool development. Exploration of how to create composite species layer, completion and incorporation of the Landscape Block/Network , integration of the data into the Crucial Areas Planning System (CAPS) and developing additional data tools and dissemination products as necessary.

In addition, activities in Phase III will be aligned with the WGA Corridor Initiative. Evaluation of a statewide connectivity prioritization process will also be used in the update of MFWP's State Wildlife Action Plan. Like the Assessment, this layer(s) will need to be revisited periodically to reflect changing conditions in our state, changing methodologies in connectivity science, new and improved data sources and the need to consider climate change scenarios.

1.3. Focal Species Selection Process

1.3.1. Connectivity Working Group

Successfully developing a connectivity layer for Montana required the coordinated efforts of many different partners whose activities include conservation planning, land use and transportation planning, and wildlife management and research. The CWG was formed in the fall 2008 to engage individuals and organizations from the local to the state to the regional scale to assist MFWP in the developing the architecture of the Connectivity Assessment. The CWG was comprised of state and federal fish and wildlife biologists, academic and NGO-based biologists. Some members of the group had multiple affiliations, interests, and areas of expertise. The work of the CWG began in December 2008 and was completed in June 2009.

Prior to the CWG forming, an initial review of vertebrate species in Montana revealed that approximately 100 species had fairly specific habitat requirements at some point in their life cycle. These species served as the initial focal species list for the Connectivity Assessment and were to be narrowed and/or enlarged based on the species' selection process as it unfolded.

The Connectivity Assessment product(s) were to be multi-scaled and consider numerous species at each scale. Scales could include regional pathways, statewide and population level corridors, as well as localized habitat movements. It is recognized that some species' connectivity requirements exist at a scale too fine for a statewide assessment. Less mobile, small animals could be impacted at a project scale and will need to be assessed at the project location. At a minimum, these species with movement needs will be identified and recognized through a narrative approach within the Assessment.

The goals of the CWG were to:

1. Create a list of focal species with reasons/justification for their selection, information used to determine important linkages for these species and/or data needed for future assessment of the species,
2. Create a statewide map of linkages ranked by their importance for selected focal species where data and resources were available, and
3. Provide a document outlining how the map was created, what components were used to make the map, process decisions and caveats associated with the information used and final product.

After the initial meeting of the CWG, the following observations were developed, which redefined the outcomes of Phase I.

- MFWP recognizes this is a unique approach to connectivity planning in that they are attempting to identify areas of crucial habitat and areas of connectivity simultaneously; the purpose is not to try and connect crucial areas at this point in time;
- MFWP considers this to be Phase I of a process that will involve several future iterations; Phase I should be as thorough and accurate as possible but the reality is that it will not be perfect;
- It is important to remember that a key product of this process is documentation of the process itself – establishing a sound methodology for mapping connectivity at the state level will set a precedent for connectivity conservation;
- In addition to advising MFWP on the development of this tool for connectivity planning, an important role of the CWG is to weigh in on how this tool should be implemented and used on the ground; and
- Given the speed with which MFWP would like to move forward in this process and their recognition that this process and the products that result from it are the first stage in an iterative process, employing the precautionary principle in making initial decisions regarding crucial areas and connectivity in Montana was recommended.

1.3.2. Terrestrial Mammals and Reptiles Focal Species Selection Process

A subgroup of the CWG reviewed three existing approaches for species selection; Landscape Species Approach (WCS), Ecosystem Umbrella Framework (Craighead Environmental Research Institute- CERI), and the draft selection process for Washington State (Figure 1). The subgroup found that all three approaches are relatively robust but decided on a modified version of the Washington process because of speed and ease of implementation and the more direct relationship to connectivity issues implicit in this approach.

The approach we used for terrestrial mammals and reptiles involved the following steps (Table 1) and were developed from a review past approaches.

- Assemble an initial list of vertebrates based on conservation status, socioeconomic value, and risk related to loss of habitat connectivity.
- Use expert opinion to identify ecological processes and types of movement related to connectivity for each species
- Use expert opinion to rank each species for its vulnerability to threats
- Assign each species to the ecological associations (habitats) they use
- Compile this information in a matrix to develop a draft list of species that represent all of the ecological processes and threats as well as connecting the different ecological systems in the state.
- Review the draft list with state scientists and refine the list to those species that best represent connectivity in the state.

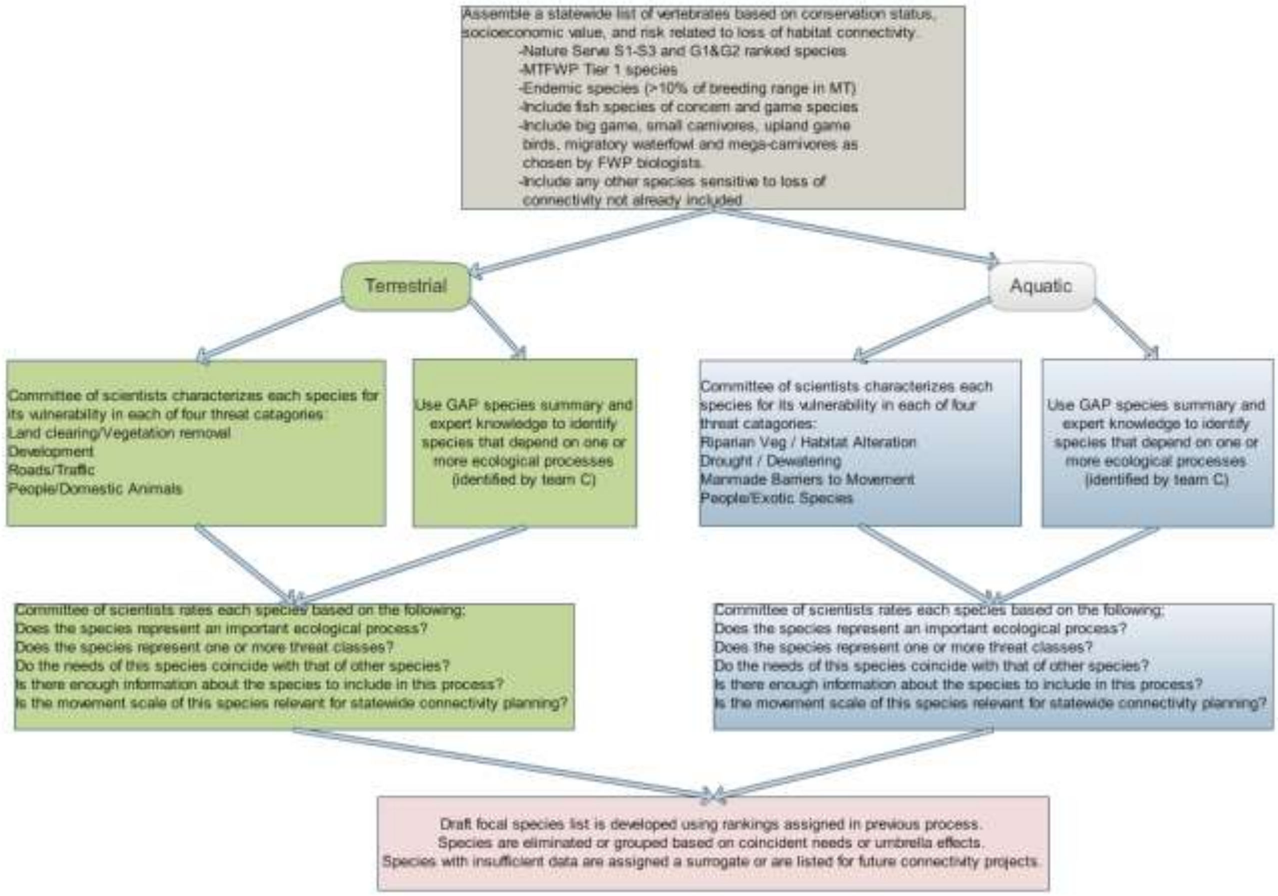


Figure 1. Focal species selection flow chart

Approach	Advantages	Disadvantages
Landscape Species Approach	▪ Is quantitative and highly repeatable. ▪ Provides metrics that can be used to measure other conservation values.	▪ Is time consuming to parameterize for large pools of candidate species. ▪ Emphasizes vagile species which may not serve as adequate umbrella for relatively sedentary but connectivity-dependent species. ▪ Would require modification to apply to choosing a connectivity specific umbrella.
Ecosystem Umbrella	▪ Requires relatively few inputs for faster implementation. ▪ Uses a priority ranked optimization process to find minimum effective set.	▪ Emphasizes species which may not serve as adequate umbrella for relatively sedentary but connectivity-dependent species. ▪ Would require modification to apply to choosing a connectivity specific umbrella.
Washington Methods	▪ Targeted specifically to connectivity ▪ Identifies most relevant connectivity threats and selection criteria ▪ Easily adapted to Montana data sources	▪ Uses conservation status criteria to narrow candidate pool which may eliminate important focal species such as migratory game species. ▪ Does not explicitly include connectivity process to insure that all "types" of connectivity are covered by the selected species suite.
Modified Washington Methods	▪ Targeted specifically to connectivity ▪ Identifies most relevant connectivity threats and selection criteria ▪ Easily adapted to Montana data sources ▪ Could be refined to incorporate an optimization process in future iterations.	Unknown; process used by Montana Connectivity Project.

Table 1. Comparison of existing focal species selection approaches.

Our initial list of species consisted of the following (Table 2):

- Species of concern in the state (S1-S3) and global (G1 &G2)
- Species having greater than 10% of their breeding range in Montana
- Species chosen for their socioeconomic value such as big game, small carnivores and mega-carnivores
- Species sensitive to loss of connectivity that were not already included

Birds		***Mammals***	
Scientific Name	**Common Name**	**Scientific Name**	**Common Name**
Pelecanus erythrorhynchos	American White Pelican	Sorex preblei	Preble's Shrew
Cygnus buccinator	Trumpeter Swan	Sorex nanus	Dwarf Shrew
Buteo swainsoni	Swainson's Hawk	Sorex arcticus	Arctic Shrew
Buteo regalis	Ferruginous Hawk	Sorex merriami	Merriam's Shrew
Centrocercus urophasianus	Greater Sage-Grouse	Blarina brevicauda	Northern Short-tailed Shrew
Tympanuchus phasianellus columbianus	Sharp-tailed Grouse (Columbian)	Myotis evotis	Long-eared Myotis
Charadrius montanus	Mountain Plover	Myotis thysanodes	Fringed Myotis
Numenius americanus	Long-billed Curlew	Myotis septentrionalis	Northern Myotis
Leucophaeus pipixcan	Franklin's Gull	Lasiurus borealis	Eastern Red Bat
Sterna hirundo	Common Tern	Lasiurus cinereus	Hoary Bat
Cypseloides niger	Black Swift	Euderma maculatum	Spotted Bat
Melanerpes lewis	Lewis's Woodpecker	Corynorhinus townsendii	Townsend's Big-eared Bat
Gymnorhinus cyanocephalus	Pinyon Jay	Antrozous pallidus	Pallid Bat
Nucifraga columbiana	Clark's Nutcracker	Ochotona princeps	Pika
Oreoscoptes montanus	Sage Thrasher	Sylvilagus nuttallii	Mountain Cottontail
Anthus spragueii	Sprague's Pipit	Lepus townsendii	White-tailed Jack Rabbit
Spizella breweri	Brewer's Sparrow	Lepus californicus	Black-tailed Jack Rabbit
Catharus fuscenscens	Veery	Brachylagus idahoensis	Pygmy Rabbit
Ammodramus savannarum	Grasshopper Sparrow	Tamias amoenus	Yellow-pine Chipmunk
Calcarius mccownii	McCown's Longspur	Tamias ruficaudus	Red-tailed Chipmunk
Calcarius ornatus	Chestnut-collared Longspur	Tamias umbrinus	Uinta Chipmunk
Dolichonyx oryzivorus	Bobolink	Marmota flaviventris	Yellow-bellied Marmot
Leucosticte atrata	Black Rosy-Finch	Marmota caligata	Hoary Marmot
Carpodacus cassinii	Cassin's Finch	Spermophilus richardsonii	Richardson's Ground Squirrel
Chlidonias niger	Black Tern	Spermophilus armatus	Uinta Ground Squirrel
Seiurus aurocapilla	Ovenbird	Spermophilus columbianus	Columbian Ground Squirrel
Selasphorus rufus	Rufous Hummingbird	Spermophilus elegans	Wyoming Ground Squirrel
		Cynomys ludovicianus	Black-tailed Prairie Dog
Reptiles		Cynomys leucurus	White-tailed Prairie Dog
Scientific Name	**Common Name**	Thomomys talpoides	Northern Pocket Gopher
Chelydra serpentina	Snapping Turtle	Thomomys idahoensis	Idaho Pocket Gopher
Apalone spinifera	Spiny Softshell	Perognathus fasciatus	Olive-backed Pocket Mouse
Elgaria coerulea	Northern Alligator Lizard	Perognathus parvus	Great Basin Pocket Mouse
Phrynosoma hernandesi	Greater Short-horned Lizard	Chaetodipus hispidus	Hispid Pocket Mouse
Sceloporus graciosus	Common Sagebrush Lizard	Neotoma cinerea	Bushy-tailed Woodrat

Eumeces skiltonianus	Western Skink	Microtus richardsoni	Water Vole
Charina bottae	Rubber Boa	Lemmiscus curtatus	Sagebrush Vole
Heterodon nasicus	Western Hog-nosed Snake	Synaptomys borealis	Northern Bog Lemming
Lampropeltis triangulum	Milksnake	Zapus hudsonius	Meadow Jumping Mouse
Thamnophis elegans		Zapus princeps	Western Jumping Mouse
Thamnophis radix	Plains Gartersnake	Canis lupus	Gray Wolf
Opheodrys vernalis	Smooth Greensnake	Vulpes velox	Swift Fox
Crotalus viridis	Prairie Rattlesnake	Ursus arctos	Grizzly Bear
		Martes pennanti	Fisher
Amphibians		Mustela nigripes	Black-footed Ferret
Scientific Name	**Common Name**	Gulo gulo	Wolverine
Plethodon idahoensis	Coeur d'Alene Salamander	Spilogale gracilis	Western Spotted Skunk
Dicamptodon aterrimus	Idaho Giant Salamander	Lynx canadensis	Canada Lynx
Ascaphus montanus	Rocky Mountain Tailed Frog	Bos bison	Bison
Bufo boreas	Western Toad	Ovis canadensis	Bighorn Sheep
Bufo cognatus	Great Plains Toad	Odocoileus hemionus	Mule Deer
Spea bombifrons	Plains Spadefoot	Odocoileus virginianus	White-tailed Deer
Rana pipiens	Northern Leopard Frog	Alces alces	Moose
Rana luteiventris	Columbia Spotted Frog	Cervus canadensis	Elk
		Antilocapra americana	Pronghorn
		Oreamnos americanus	Mountain Goat
		Martes americana	Marten
		Lynx rufus	Bobcat
		Lontra canadensis	Northern River Otter
		Ursus americanus	Black Bear
		Puma concolor	Mountain Lion

Table 2. Initial list of species used for focal species selection process.

These species were placed in a matrix that was sent to biologists for characterization of ecological processes and vulnerability to threats (Figure 2). The ecological processes included were:

- Home range movement (species whose home ranges exceed habitat patches)
- Avian migration (long distance with staging areas and stopovers)
- Avian migration (shorter movement between habitat types to satisfy life stage needs)
- Long distance migration (terrestrial movement to/from seasonal ranges)
- Long distance movement (long distance walk-about i.e. wolverine, wolf)
- Metapopulation connectivity (where source/sink processes exist)
- Dispersal (movement necessary for genetic connectivity)
- Range expansion (movement into currently unoccupied or previously disturbed habitats)

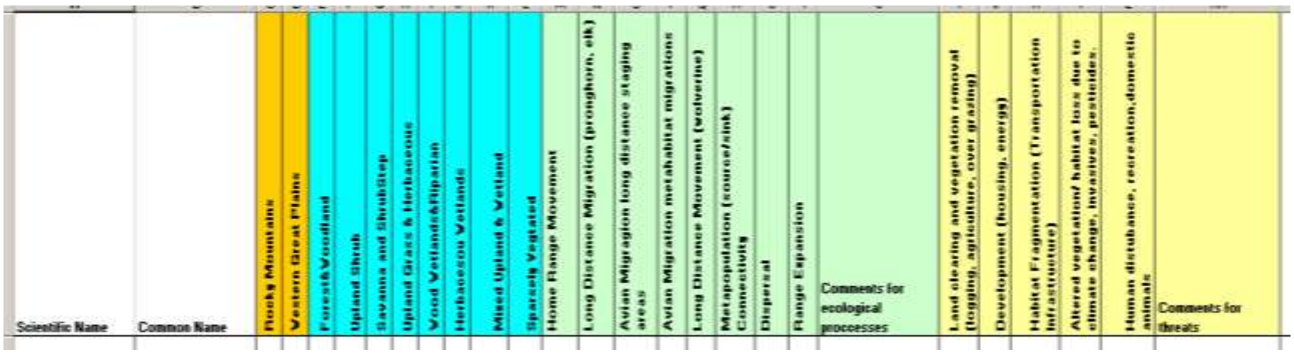


Figure 2. Species selection matrix headings.

Vulnerability to threats was ranked on a scale of 1-3 where 1 is small scope with less severe impacts and 3 is wide scope with severe impacts on the species. The threats included were:

- Land clearing and vegetation removal (logging, agriculture, intensive grazing)
- Development (housing and energy)
- Habitat fragmentation due to transportation and related infrastructure
- Altered vegetation due to climate change, invasive species and pesticide use
- Human disturbance through recreation and domestic animals

In order to assure that connectivity between all ecotypes were included, we used the general ecological associations developed by Natureserve with a geographic component that distinguished western Montana ecotypes from eastern Montana ecotypes. Each species was assigned one or more ecological associations using a system developed by the Montana Natural Heritage Program (MNHP). This system used ecological systems identified from previous GAP, habitat use summaries from the literature, expert opinion and the number of species occurrence records falling within each association. These products were used to rank associations for each species-ecotype combination as high, medium, or low. Associations ranking 'high' were included in the selection process to reflect the habitat types for which each species would make the most suitable surrogate.

Each species was then scored based on processes and threats. This was accomplished by summing the total number of processes associated with each species to derive a process score, and the sum of individual threat scores to derive a total threat score. For each primary division (ecotype combination), species were sorted by their process score and then by total threat score to rank species first by total number of connectivity processes they depend upon, and then by their vulnerability to loss of those processes. The top five ranked species for each primary ecological division-ecotype combination were selected as candidate focal species.

Additional species were added to assure that all processes, threats for each ecological association were covered. This was accomplished by identifying gaps in coverage and selecting the highest ranked species (according to the sorting process described above) that would cover that gap to obtain a preliminary list of focal species (Table 3).

Mammals	Amphibians
Wolverine (W)	Western Toad (W)
Canada Lynx (W)	
Fisher (W)	
White-tailed Prairie Dog (B)	**Reptiles**
Moose (W)	Prairie Rattlesnake (B)
Bushy-tailed Woodrat (B)	Plains Gartersnake (W)
Pika (W)	Terrestrial Gartersnake (B)
Gray Wolf (W)	
Mountain Lion (B)	
Hoary Marmot (W)	
Mule Deer (B)	
Elk (B)	**Semi-Aquatics**
Black-footed Ferret (E)	Northern River Otter
Bobcat (B)	Northern Leopard Frog
Townsend's Big-eared Bat (B)	Beaver
Fringed Myotis (W)	Columbia Spotted Frog
Long-eared Myotis (W)	Spiny Soft Shelled Turtle
Spotted Bat (B)	Snapping Turtle
Pallid Bat (B)	
Hoary Bat (B)	

Table 3. Preliminary terrestrial mammal, reptile, and semi-aquatic focal species list for connectivity assessment, (Geographic association in final selection matrix; W= western Montana E = eastern Montana, B = both western and eastern Montana.)

1.3.2.1. Final Species Selection

After a final review by the CWG, a finalized focal species list was designated (Table 4) with the understanding that;

- Satisfying the connectivity needs of the species on this list will satisfy the connectivity needs of all vertebrate species in Montana based on current ecological processes and threats (climate change has not been factored in).
- It is possible that there is redundancy in the list relative to connectivity on the landscape. This will become apparent as mapping proceeds. At that time some species may be removed from the list if they fall under the "umbrella" of another species.
- Every effort will be made to model/map connectivity for all species, even where data is limited. However, if data is entirely lacking for a focal species, a surrogate species representing similar processes and threats may be used until more information becomes available.
- Because the focal species represent multiple scales of connectivity on the landscape it may be necessary to map them in separate groups based on scale.
- The focal species list will be adjusted in the future as more information on Montana's biota becomes available, and as conditions in Montana change.

Mammals	Mammals (cont)
Wolverine	Fringed Myotis
Canada Lynx	Spotted Bat
Fisher	
Bobcat	
Swift Fox	**Amphibians**
Elk	Western Toad
Moose	Great Plains Toad
Pronghorn	
Mule Deer	**Reptiles**
Gray Wolf	Prairie Rattlesnake
Mountain Lion	Plains Gartersnake
Grizzly Bear	Terrestrial Gartersnake
Black Bear	
Hoary Marmot	**Semi-Aquatics**
Pika	Northern Leopard Frog
Pygmy Rabbit	Northern River Otter
White-tailed Prairie Dog	Snapping Turtle
Black-tailed Prairie Dog	Beaver
Townsend's Big-eared Bat	Idaho Giant Salamander
Hoary Bat	Spiny Soft Shelled Turtle
Pallid Bat	

Table 4. Finalized terrestrial mammal, reptile, and semi-aquatic focal species list that will be used to address connectivity in Montana.

1.3.3. Semi-Aquatic Focal Species Selection

Due to their unique connectivity needs, semi-aquatic species were selected differently than terrestrial mammals and reptiles. The initial process assigned each species a watershed rather than an ecoregion. Processes and threats were scored and summed by the same approach used for the terrestrial species. The top ranked species for each watershed were selected as the candidate semi-aquatic focal species (Figure 3).

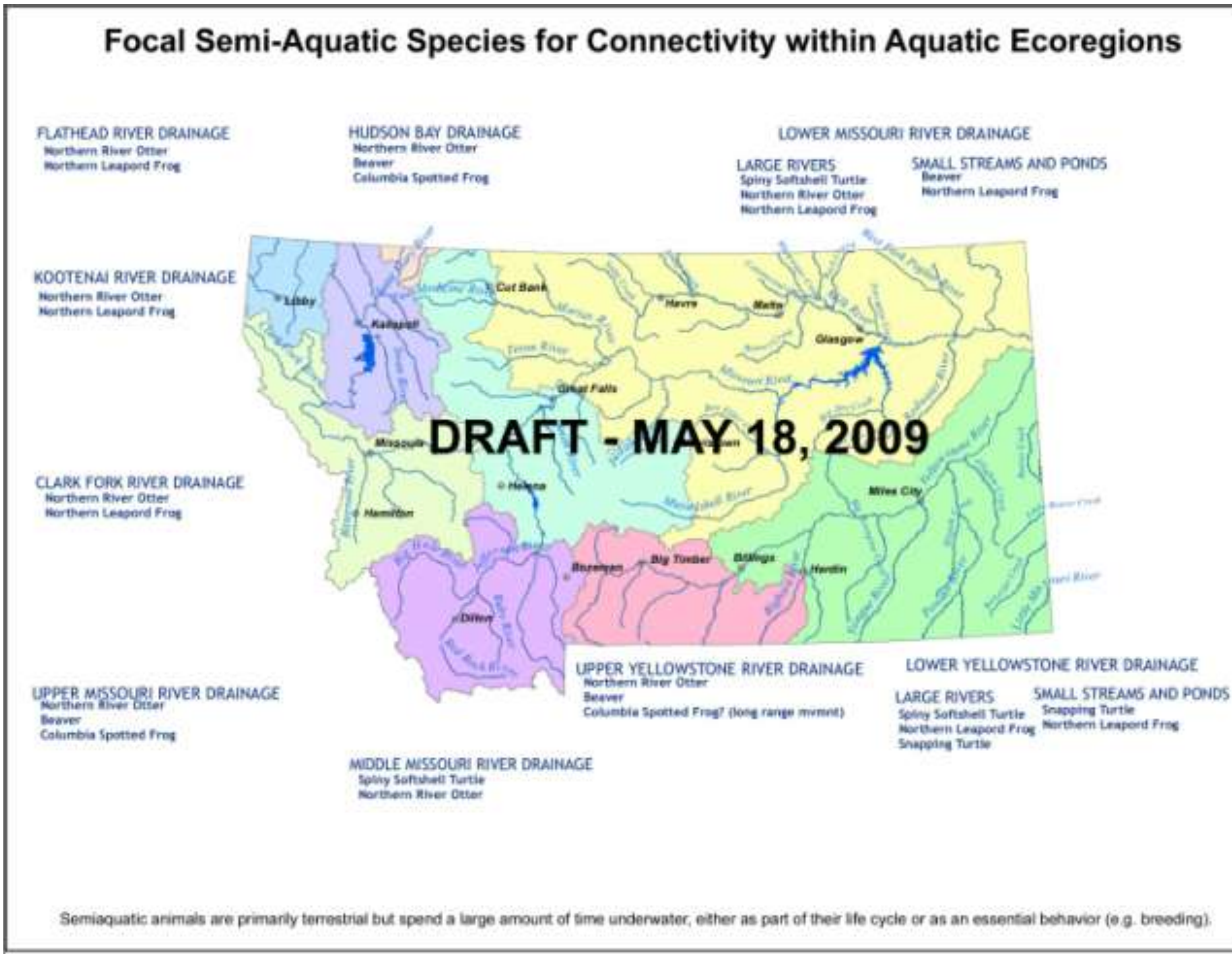


Figure 3. Watershed based approach for selecting semi-aquatic focal species

1.3.4. Bird Species - Definitions and Species Selection Process

Bird species also have unique connectivity needs and thus were selected by bird experts in the state through a separate process. Many bird species are migratory and all native birds in Montana have some ability to fly among habitat patches. Thus, the traditional concept of connectivity as physical corridors that link landscapes is difficult, and at times inappropriate, to apply to birds. Therefore, we developed the following working definition of connectivity for birds that serves 'to maintain or increase essential genetic and demographic connection of populations':

Connectivity for birds requires high quality, contiguous patches of breeding habitat and intact, functioning migration and wintering habitat at the appropriate scales.
Specifically, corridors for birds include maintenance of:

1. Large, contiguous, and well-distributed patches of native grassland, shrub-steppe, shrub, forest, woodland, and alpine habitats to facilitate genetic exchange of breeding birds (specific requirements will vary by species and habitats).

2. Native riparian vegetation and natural stream flow regimes that provide important breeding and migration habitat for some songbirds, raptors, waterfowl, and shorebirds.
3. Dispersed wetlands with heterogeneous wetland conditions that provide breeding, migration and wintering habitat for waterfowl, waterbirds, and shorebirds.
4. Rangeland, agricultural, and forested lands for winter residents.

1.3.4.1. Threats Analysis

Threats to connectivity described for the terrestrial and semi-aquatic species are also applicable to birds. We separated housing and energy development, as the types and locations of impacts may be quite different; climate change from invasive species and pesticides threats and added a noise category. Recent research indicates fragmentation caused by noise (e.g., road traffic) far exceeds the physical footprint of the source (e.g., road). Thus, threats for birds include:

- Land clearing and vegetation removal (logging, agriculture, intensive grazing)
- Housing development
- Energy development
- Habitat fragmentation due to transportation and related infrastructure
- Functional habitat fragmentation resulting from noise avoidance
- Altered vegetation and water resources due to climate change
- Altered vegetation due invasive species or pesticide use
- Human disturbance through recreation or domestic animals

We started with a list of all birds commonly occurring in Montana recorded in MNHP Point Observation Database (POD). We worked through several iterations of developing the list. At each iterative step, we assessed habitat and potential threats associated with all species on the list to determine if there were threats to connectivity that were not captured. To add species to the list, we identified the species that most directly addressed the missing component with the greatest proportion of breeding, migration, or winter range in Montana and for which we had the most comprehensive information.

- Our initial list included all bird Species of Concern with ≥5% of their breeding population in Montana. We chose to focus on Species of Concern in Montana because populations of these species are typically declining or threatened. We also chose to focus on those SOC who have ≥5% of their breeding range in Montana because loss of habitat in Montana for those species will likely have significant impacts to range-wide population trends.
- Species on this initial list represented most habitats, but we felt the special habitat requirements of some species for mountain streams or gravel bars in large rivers were absent. We added 2 species, Harlequin Duck and Piping Plover, respectively, (4% of continental population breeds in MT for each), and we have relatively good information on habitat requirements and distribution for both.
- Mature coniferous forest habitats for birds were also underrepresented on the initial list. We added Brown Creeper to represent this habitat type. Brown Creeper is a Species of Concern, 4% of their continental population breeds in Montana, and we have reasonably good information on this species from the Northern Region Landbird Monitoring Program.

- We added Common Loon because this species has documented connectivity needs, such as limited dispersal from natal lakes in discrete locations and wintering populations in southwestern Montana. This species will likely be very sensitive to residential development, recreation, and climate change.
- Alpine habitats are also expected to be very sensitive to changing climates. Shrinking alpine habitats will likely make populations of alpine birds more isolated and thereby reduce genetic exchange among those populations. Our only alpine species on the initial list, Black Rosy-Finch, has a relatively limited distribution. We added White-tailed Ptarmigan to provide more comprehensive coverage of alpine habitats.
- Ephemeral wetland conditions during the breeding season were not captured well. We added Wilson's Phalarope (10% of continental population breeds in MT) to represent the more ephemeral wetland hydroperiod.
- Heterogeneous wetland conditions during the non-breeding seasons were also not captured adequately. We added Long-billed Dowitcher, Northern Pintail, and Tundra Swan to capture shallow, intermediate, and deeper water requirements, respectively.
- Lastly, we had no representatives for connectivity of winter habitats. This is more difficult to capture, in part because we have less information on wintering bird distribution and habitat associations. We added 2 wintering species for which we do have reasonable information. The Rough-legged Hawk is widely dispersed in Montana in winter but also has concentrated use areas. Trumpeter Swans complete their migration cycle in Montana, occupying both breeding and wintering wetland areas (Table 5).

American White Pelican	Clark's Nutcracker	Ovenbird
Baird's Sparrow	Ferruginous Hawk	Pinyon Jay
Black Rosy-Finch	Franklin's Gull	Piping Plover
Black Swift	Grasshopper Sparrow	Rough-legged Hawk
Black Tern	Greater Sage-Grouse	Rufous Hummingbird
Bobolink	Harlequin Duck	Sage Thrasher
Brewer's Sparrow	Lewis's Woodpecker	Sharp-tailed Grouse (Columbian)
Brown Creeper	Long-billed Curlew	Sprague's Pipit
Cassin's Finch	Long-billed Dowitcher	Swainson's Hawk
Chestnut-collared Longspur	McCown's Longspur	Trumpeter Swan
Common Loon	Mountain Plover	Tundra Swan
Common Tern	Northern Pintail	Veery
White-tailed Ptarmigan	Wilson's Phalarope	

Table 5. Finalized bird focal species list that will be used to address connectivity in Montana.

1.4. Focal Species Prioritization

The CWG identified 76 focal species to serve as the basis for building connectivity layers for Montana. Given the resources available both for the species themselves and the staff time needed to generate the connectivity layers, it was deemed unlikely that all species would be able to be completed. A Species Connectivity Experts (SCE) Committee was convened in May 2010 to rank the species into a prioritized listing based upon several criteria. The SCE assessed the current biological understanding of the focal species, type of connectivity to be assessed, data availability, the ability to serve as umbrella species and the level of threats.

Focal species prioritization occurred through the following steps:

- Threats and umbrella scores for each species were obtained from experts before and during the SCE meeting.
- The threats and umbrella scores were added to get a total score for each species. These total scores were then averaged across all experts. Species were placed in order of their average total scores.
- All species listed as falling under the umbrella of a higher scoring species were moved to the bottom of the list where they occur in order of their average total scores. For instance, Harlequin duck was replaced with Trumpeter swan because they utilize similar habitats and more information is available for the latter species.
- The final step was to move two species (wolverine and black bear) to the top of the list because current, range-wide linkage maps have been made for these species.

This order was considered preliminary as data availability dictated a species be replaced by a surrogate or mapped at a future time when more information is available. Appendix C lists for each focal species their priority, general habitat types used by a species, the types of connectivity needed for species persistence, threats faced, other species that may benefit by conserving connectivity for this species, and connectivity data that is known to be available for this species in Montana. Further refinement to the list occurred during the process and will be covered under Section 2, Methods.

2. METHODOLOGY

2.1. General Methods

The approach for building connectivity layers for the prioritized focal species followed the same general pattern. Variability in the specific parameters used was dependent upon the species or species group. In general, mapping habitat connectivity for species consisted of first identifying core habitat patches, generating a representation of cost for the movement of species between those core habitat patches and then modeling the connectivity between these cores to obtain a representation of the permeability of the landscape.

We employed three general approaches to accommodate the different approaches we took to model a species, model a guild of species, and model a species using the landscape blocks. Common methodologies are presented below, with more detailed methodology and results presented by species or species guild.

2.1.1. Connectivity Principles

Core habitat can be best described as blocks of habitat that are “Living Habitat." This habitat is needed for animals to obtain food, find shelter from the elements or predator and reproduce. Habitat cores may be used continuously, seasonally, or intermittently over a period of years but they are important for maintaining the species in a region over long time periods (decades to centuries or longer). Core habitat can be defined at a variety of scales. The size needed for an individual home range, a patch that provides forage and security for a herd winter range, or an area large enough to maintain a sustainable population are just a few examples.

Movement habitat are areas that allow individuals to move between discrete habitat patches. Specific areas of movement are known as “corridors” or “linkages.” The latter term is often preferred to avoid the assumption that movement follows a relatively straight and narrow path like a hallway corridor. Although such "straight line" movement can occur, movement is more often less predictable. Good movement habitat typically provides multiple possible pathways - a continuum of pathway options - to complete a connection. Movement habitat may differ significantly from a species’ preferred habitat in terms of vegetation, topography, and other features. Some species are strictly tied to rather specific habitats and movement habitat may consist of ribbons or “stepping stones” that allow animals to move from one patch of core habitat to another without actually having to leave their preferred habitat for more than brief periods. Other species may move widely across habitat that is markedly different from areas in which they are typically found. As with habitat cores, movement habitat can be defined at multiple scales with different frequencies of use. For example, movement habitat may be areas that connect discrete patches of suitable habitat that collectively comprises an individual’s home range. In this case, the frequency of movement may be relatively high. Or movement habitat may connect areas of seasonal use, such between summer and winter range. In this case, the frequency of use may be only once or twice a year. Or finally, movement habitat may allow individuals to disperse to distant habitat patches. Such movements may be extremely rare with many years passing between events. Such movements may be critical for maintaining genetic diversity needed for the long term survival of the species, or to facilitate recovery into habitats where the species has been extirpated. It is important to understand the type of movement required for determining the frequency of movements a linkage zone may experience, but isn't necessary for identifying the location and quality of linkage zones.

Preferred habitats are areas where a species is most likely to be found, where they feel most secure, and where their chance of survival is greatest. This is important for predicting the quality of connectivity in an area. The basic assumption is that given the opportunity, individuals will stay in or near their preferred habitat even when moving between habitat patches. It is also assumed that individuals in or near preferred habitat will feel more secure and therefore be more tolerant to disturbance than individuals in marginal habitats.

Landscape connectivity has been defined a variety of ways (Tischendorf and Fahrig 2000b). Connectivity is defined structurally as the relationship between core habitat patches in terms of size, adjacency, amount of shared edge, and distance. This type of connectivity is scale dependent. Connectivity is defined functionally as the combination of structural connectivity *and* the behavioral responses of individuals to landscape structure. It is the degree to which an organism can perceive the landscape as connected or use patches to move within the landscape (With et al. 1999). This type of connectivity is both scale and subject dependent. Connectivity is an attribute of the whole landscape (Tischendorf and Fahrig 2000a) – habitat as well as matrix.

For the purposes of this analysis, connectivity is operationally defined as a process-oriented property of a landscape that permits movement of organisms. Such movement may help to maintain and/or increase population persistence and resiliency, species and genetic diversity, and ecosystem processes, including the interchange of genetic information.

In the species specific analysis, connectivity facilitates the following types of movement:

- Home range movement (species whose home ranges extend beyond one or more habitat patches, this may include movement for foraging)
- Long distance avian migration (movement using staging areas and stopovers)
- Shorter distance avian migration (movement among habitat types to satisfy life stage needs)
- Long distance migration (terrestrial movement to/from seasonal ranges)

- Long distance movement (long distance walk-about as typified by wolverines and wolves)
- Metapopulation connectivity (movement where population source/sink/extirpation processes exist)
- Dispersal (movement necessary for genetic connectivity, e.g., movement from natal ranges)
- Range expansion (movement into currently unoccupied habitats)

Spatial and temporal scale

Connectivity has both a spatial and temporal component (Figure 4). That is, connectivity is a characteristic associated with movement over small or large geographic areas, such as within a home range or across a species entire range respectively and at all levels in between. Similarly, connectivity -- specifically the movement facilitated by it -- happens over short and long timeframes, such as minutes or multiple generations respectively and at all levels in between. Organismal characteristics, which are both a function of space and time, are also strongly related with connectivity. For example, the life history, morphological, and behavioral characteristics of a species influences how connectivity may facilitate the movement of genes, individuals, or populations across a landscape in both space and time.

There are multiple scales of connectivity inherent in the list of focal species identified for this analysis. Scales include intra home-range movement, regional pathways, and population and statewide level connectivity. Some species' connectivity requirements exist at a scale that will unlikely be handled with this statewide assessment; those may include less mobile, smaller animals that could be impacted at a localized spatial scale.

Mapping and species interaction scale

Scale is applicable in two distinct but related ways in this analysis. The first relates to the scale at which mapping takes place. In this regard, coarse scale indicates relationships associated with the representation of data. For example, larger raster cell sizes (e.g., 1 ha or 1 km) mean a more generalized representation of the landscape. Thus the nuances of core habitat shape or content may be fuzzy or abstracted to a more generalized level. Alternatively, fine scale indicates the inverse. Smaller raster cell sizes (e.g., 30 m or 90 m) mean a more specified representation of the landscape -- streams would be more sinuous and patch content less abstracted. For this project, most analyses conducted in a raster environment 90 m data. Ultimately, the information associated with core habitat patches and connectivity will be displayed at a 1 m^2 resolution.

The second relates to the level at which a species interacts with the landscape. Coarse scale may indicate species interactions at the ecosystem level, for example seasonal migration movements.

Whereas fine scale may indicate species interactions while undertaking daily foraging movements. Attempts were made to conduct core patch delineations sensitive to the scale at which each species interacts with the landscape. Parameters were used to represent an ecological neighborhood for each species, for example average dispersal or foraging distances, as well as breeding and population patch sizes. Cell size for the habitat suitability maps was 90 m.

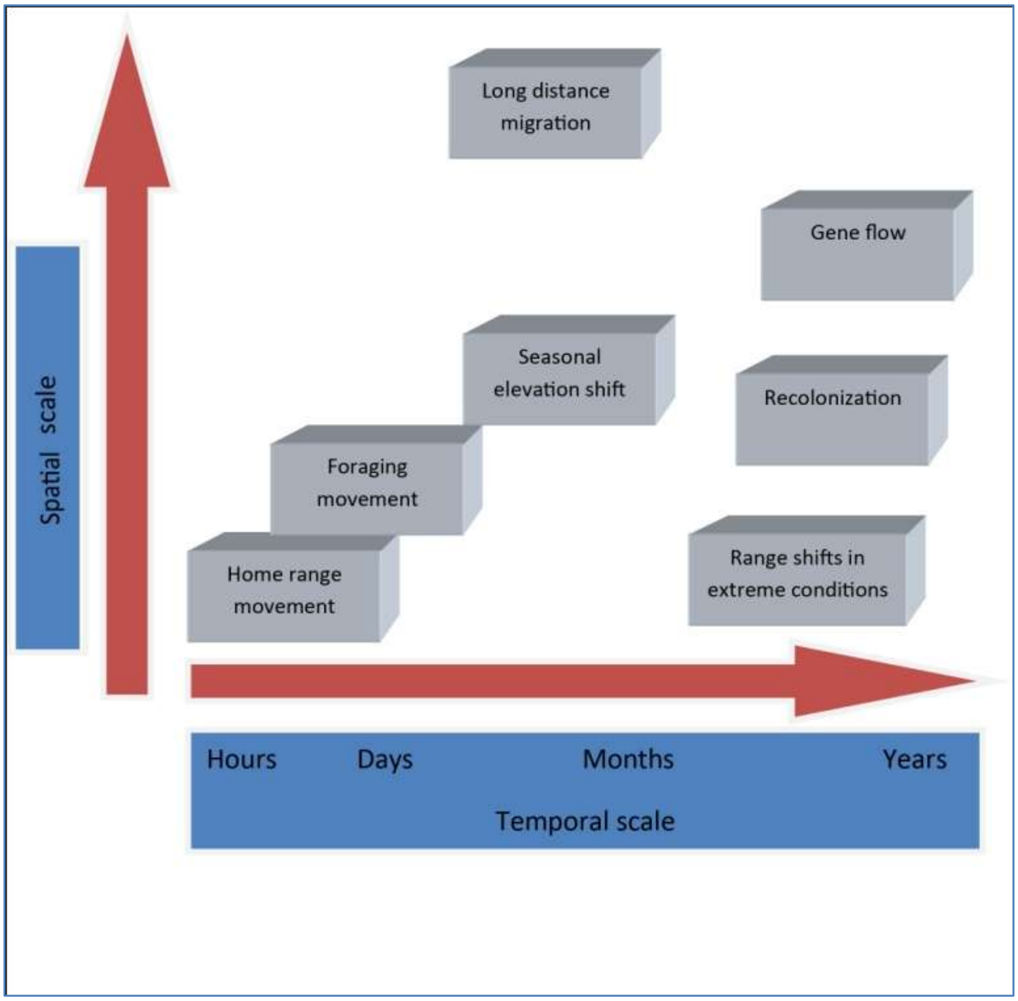


Figure 4. Scales at which connectivity operates and examples of specific types of movement that may occur at a particular spatial and temporal scale.

2.2. Species specific models

Species specific models were used when the species already had an existing model of habitat suitability.

Habitat Suitability: In most cases habitat suitability was represented through MaxEnt models, while the model and results for Wolverine were provided by WCS. The MaxEnt models were generated as part of the CAPS data generation process. These habitat suitability models are based upon characteristics at known locations and background characteristics based upon data from randomly selected pseudo-absence points.

MaxEnt is a machine learning technique that uses presence-only data to develop a niche-based model to predict a species' realized ecological niche, and by extension, the geographic space the species occupies. MaxEnt modeling provides an estimated target probability distribution by finding the distribution of maximum entropy, closest to uniform, given incomplete information about presence and a set of feature constraints, such as climate variables, soil, elevation, and land cover (Appendix D).

Many possible environmental factors may influence the actual area occupied by a species including geographic barriers to dispersal and human modifications to the landscape. Thus the predicted habitat suitability may be modified by accounting for areas the species is known not to occupy. For example, areas of the landscape in agricultural production may not be occupied by a species due to land cover conversion.

Patch (Core Habitat) Generation: The “Create Patches” tool in Corridor Designer was used to identify areas that met a suitability threshold, combined areas within a specified perception distance, and met a minimum breeding and population patch size. We used the listed parameters to identify patches and selected the 20 largest patches. This number was arbitrary and selected to limit computational requirements of modeling greater numbers of patches. In practice the breeding and population patch sizes were never limitations in the delineation of patches, since the smallest patch generally exceeded the population patch size.

Connectivity analysis The connectivity analysis for a species may be one of several types:

- LINKAGES - These are actual pathways connecting habitat blocks, or identifying linkages across fracture zones. Most terrestrial species will have this type of connectivity.
- STEPPING STONES - These are isolated blocks of habitat that serve as stopover habitat. Migratory birds will typically have this type of connectivity habitat.
- PATCHES/CONNECTIVITY - These are areas where species movements occur at a very small scale within and amongst patches of suitable habitat.

2.3. Species Guild Models

Species guild models were used to represent suites of prioritized focal species with generally similar patch and movement parameters. The guild approach was identified as providing the ability to group individual species where behavioral responses that would allow specific parameterization did not differ greatly from one species to another. This approach was used for: waterbird, raptor, shorebird and semi-aquatics guilds. This technique followed the same process as individual species of identifying patches and running connectivity models between source and destination patches.

2.4. Landscape Block Species and Ecotype Models

Most game species did not have habitat suitability models that could be used to identify core habitats. The general type of movement that was identified as important was seasonal movements from winter to summer ranges. As a result, we took two approaches to identifying important connectivity habitats for game species. The first was an expert knowledge approach where individual biologists were asked to identify areas where they had documented movement. The completeness of this information varied depending upon the knowledge of the biologists and their opportunity to document this behavior but did not create a statewide representation. To gain a more comprehensive view of the potential areas for movement across the state we utilized a product generated from our Large Landscape Block analysis.

MFWP used a landscape integrity approach to identify large areas of native habitat that might represent source and destination patches for a game and non-game species. This technique identified native habitat, removed areas that had been anthropogenically altered and selected the largest remaining intact areas. We termed these areas “Large Landscape Blocks (LLB)”. We used these blocks to help represent source and destination patches for species without habitat suitability models. Once these models were run, we continued to refine the process to explore ecotype connectivity.

Using the LLBs, we characterized these blocks to distinguish between general ecotypes. The first iteration focused on all native habitats, while additional efforts focused on alpine, forest, and grass/shrub ecotypes. In addition, forested ecotypes were viewed through a species lens to reflect dense forest preferred by forest specialist and patchy forest preferred by forest generalists. The same general technique was used to identify source and destination core patches using LLBs. Cost surfaces were generated for each ecotype using the same habitat and anthropogenic factors that went into the formation of LLBs. The connectivity modeling then followed the same technique described for the species specific models.

Please note that the methods for the LLB species models were a first draft iteration influence by the species being modeled. The second phase of this work looked at LLB ecotype based characteristics only. As such these two products are not equivalent .

2.5. Connectivity Modeling Technique

Given the number of species to be modeled, our experience and expertise and available data, we explored three approaches for modeling connectivity which included circuit theory using Circuitscape, graph theory using Funconn, and cost-distance analysis (Appendix E) . Trials with Circuitscape were promising but the resulting maps were more difficult to interpret because of the models tend to produce “stringers” of charge into the landscape that are not directed toward suitable habitat. Circuit models were also computationally intensive require long runtimes to generate models. Graph theory was also considered because of its ability to rank the relative importance of linkages. However, we had difficulties getting the software to run and we felt that the graphical output would be more difficult for reviewers to interpret and yielded less useful information for delineating geographical boundaries for conservation priorities.

We ultimately chose cost-distance analysis because we were experienced with this method; models are relatively intuitive to parameterize, explain or evaluate; and the resulting maps are relatively easy to interpret. At the time the project began, “Corridor Designer” was available for modeling and mapping wildlife linkage corridors. We explored use of this tool but determined it wasn’t suitable for the project purpose. Corridor Designer simplifies the process of mapping the best corridor connecting two habitat blocks when the linkage between the two blocks are known or assumed because it will always delineate a corridor regardless of the strength or functionality of the linkage area. However Corridor Designer was used to delineate major habitat patches used as sources for cost-distance analyses.

Because we made no assumptions about the location or strength of linkages and relied on the models to identify areas of potential linkage, we opted for an advanced cost-distance modeling technique that computes multiple pair-wise comparisons of least-cost corridors between habitat patches. These corridor surfaces are then mosaiced to produce a composite map of linkages between all pair-wise combinations.

To automate this process, we developed a suite of tools called “Linkage Assistant”. Linkage Assistant automatically loops through a list of user-determined habitat patch combinations and generates pair-wise corridor, a composite linkage map, and a map that divides corridors into n^{th} percentile slices. The Washington Wildlife Habitat Connectivity Working Group developed a “Linkage Mapper” in 2010 which was not available when we began this project. Both toolkits are similar in that they model pair-wise least-cost corridors between habitat patches and produce composite maps.

2.6. Area of Extent

The area included in our analysis was generally limited to the extent of the state of Montana. While in some cases the data inputs and outputs extended beyond Montana, our final output layers were restricted to the state boundary. For example, when modeling many of the bird species we included pseudo-core habitat patches in specific locations outside of Montana to represent expected source and destination locations for movement into and out of the state. In some cases output layers were restricted to the distributional range of the species.

2.7. Data Review and Refinement

All our modeling efforts required making assumptions about the response of species to habitat which influenced the resulting core habitat delineations and connectivity models. To ensure that the models generated were an adequate representation of on the ground conditions, the SCE was provided all results as they became available and asked to provide feedback. This was accomplished through application of a Data Review mapping application coupled with a Survey Monkey questionnaire to collect specific comments (Figure 5).

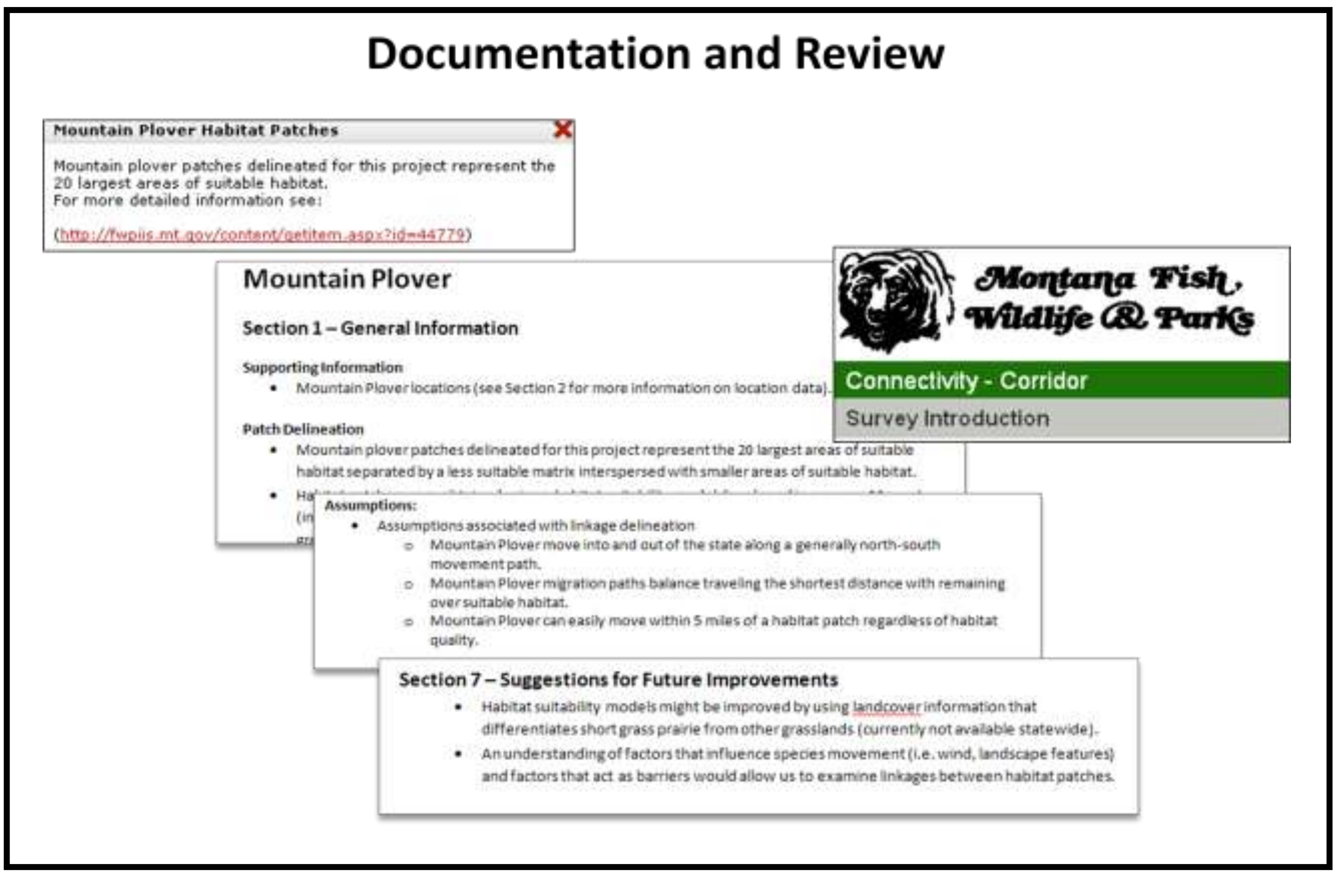


Figure 5. Example of Data Review using "Survey Monkey".

2.8. Data Confidence Rating

Connectivity modeling is a relatively new process. Therefore, research and supporting data to parameterize and evaluate model results was limited to nonexistent. This was especially true considering the statewide extent at which modeling efforts were conducted. Data review consisted of qualitative evaluations of the modeling results. Quantitative evaluation, while preferred, could not be completed at this stage. Through the data review process the project team obtained feedback that was used to assign a confidence rating to the habitat suitability models, core habitat patch delineations and connectivity model results. Confidence ratings were assigned a value of high, medium, low and not evaluated. These ratings were generated by project team members. Additional review is being undertaken prior to release of the data. Core and connectivity ratings are provided in the header section of each individual report as well as in an Appendix L.

The ratings consist of several metrics across the three primary products (MaxEnt/Habitat Suitability Models; Core Patches and Connectivity Models). Those metrics are:

- Results Quality – Rating of the relative strength of the final product.
- Source Data Quality – Rating of the strength of information used to produce the final product.
- # of Reviewers – Estimate of the number of reviewers. This number may be low, as many undocumented conversations occurred throughout the process.
- Current Understanding – Rating of the current level of knowledge of what the product represents.
- Rating Consistency – How consistent the reviewers were in their assessment of the quality of the data.

Values for the ratings are on a relative scale of High, Medium and Low. In addition there are 3 additional qualifiers.

- N/A – The category is not applicable to the metric.
- NE – The category was not evaluated.
- DNU – The reviewers indicated that the data should not be used in its current form.

3. RESULTS

The following results of our connectivity analysis is for 25 species and 4 guilds and are organized based upon the method used: (Table 6)

- Species Specific Models
  - 11 Birds; 5 Mammals; 1 Amphibian
- Species Guild Models
  - Raptor, Waterfowl and Shorebird - Avian groups
  - Semi-aquatic group
- Landscape Block Based Species and Ecotype Models
  - 8 Mammals
  - 4 Ecotypes (Alpine, Forest Generalist, Forest Specialist, and Grass/Shrub)

Mammals	**Birds**	**Semi-Aquatics Guild**	**Raptor Guild**
Black Bear	Baird's Sparrow	Beaver	Ferruginous Hawk
Black-tailed Prairie Dog	Black Rosy-Finch	Northern River Otter	Rough-legged Hawk
Elk	Cassin's Finch	Spiny Soft-shelled Turtle	Swainson's Hawk
Grizzly Bear	Clark's Nutcracker	**Waterbird Guild**	**Shorebird Guild**
Lynx	Ferruginous Hawk	American White Pelican	Long-billed Curlew
Moose	Greater Sage-grouse	Black Tern	Long-billed Dowitcher
Mountain Lion	Long-billed Curlew	Common Loon	Mountain Plover
Mule Deer	Mountain Plover	Common Tern	Piping Plover
Pronghorn Antelope	Piping Plover	Franklin's Gull	
Pygmy Rabbit	Rufous Hummingbird	Northern Pintail	
Swift Fox	Trumpeter Swan	Trumpeter Swan	
Townsend's Big-eared Bat	**Amphibian**	Tundra Swan	
Wolverine	Northern Leopard Frog	Wilson's Phalarope	

Table 6 : Species included in the Montana Connectivity Project – Color coded by habitat type: Forest Specialist; Forest Generalist; Grassland/Shrub; Shrub-steppe; Riparian/Wetland; Alpine)

3.1. Species Specific Models

3.1.1. Baird's Sparrow (<u>Ammodramus bairdii</u>)

Group: Avian

Ecosystem: Grasslands

Type of connectivity: Seasonal migrant

Global/State Species of Concern Rank: G4/S3B

Confidence Rating: Core (Low) Connectivity (Low)

Figure 6. Baird's Sparrow Range

Introduction: Baird's Sparrow is a seasonal migrant that breeds in Montana. It is commonly associated with Grassland, Wetland/Riparian, and Shrub ecological systems of eastern Montana. Baird's sparrows prefer to nest in native prairie, but structure may ultimately be more important than plant species composition.

Baird's Sparrow was added to the state SOC list in 1992; however the proximate reasons are undocumented. Baird's Sparrow was selected as a focal species to represent grassland environments, due to the fact that it is a SOC with greater than 5% of its breeding range in Montana. Baird's sparrow serves as an umbrella species for Sprague's pipit and longspurs (with short grass).

Because a relatively complex structure is so important for nesting, areas with little to no grazing activity are required. Management recommendations specific to the Baird's Sparrow in Montana include: preservation of remaining native grassland habitat; prescription burning of areas to prevent encroachment by woody vegetation; delayed mowing until mid-July or August (later, rather than sooner, if spring weather has been adverse); light grazing; and maintaining vegetative diversity (Casey 2000).

Section 1 – General Information
Supporting Information

- Baird's Sparrow locations (see Section 2 for more information on location data).

Patch Delineation

- Baird's sparrow patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having an average value greater than a given suitability threshold and within a 1600 hectare area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).
- Habitat patches may have been adjusted based on feedback from species experts.

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the percent area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
    - The habitat suitability model adequately represents landscape conditions preferred by Baird's sparrow.
    - The parameters listed in Section 3 for patch development generally represent Baird's sparrow behavior.
    - The selected habitat patches include the largest and "best" areas supporting Baird's sparrow.
- Assumptions associated with connectivity analysis.
    - Movement between stop-over and breeding sites is less influenced by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
    - Baird's sparrows move into and out of the state along a generally north-south movement path.
    - Baird's sparrow migration paths balance traveling the shortest distance with remaining over suitable habitat.
    - Baird's sparrows can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment
A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
    - Baird's sparrow locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program (MNHP). Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than 400m. A total of 439 locations were used for model training and 146 locations were used for model testing.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
    - AUC from test data = 0.964. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation
We used the Create Habitat Patch tool provided by CorridorDesigner (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on Baird's sparrow literature (Dechant et al 2002, Lane 1969, Sousa 1983).
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 3
    - Perceptual distance (how far away is suitable habitat perceived) = 320 meters
    - Population patch size (minimum area needed to support a population) = 1600 hectares. Based on area needed to reduce Brown-headed cowbird parasitism.
    - The 20 largest patches were used to represent the major areas supporting Baird's sparrow.
    - Patches were reviewed by area biologists and feedback was used to make adjustments to the patches. (Appendix F). The final layer consists of 22 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.
The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Two methods were used generate linkages:
  - Method 1 (basp_cor1.img)
    - Corridor rasters were generated between patch regions with "most likely" connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch 2 as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.

    - Additional corridors were calculated between each of the border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow birds to migrate from the state boundaries to each patch region.

  - Method 2 (basp_cor2.img):
    - Corridors were only generated between each of the state boundary patches and each patch region. This method is based on the assumption that birds migrating into the state to breed will navigate from the boundary to their final nesting destination along the best available habitat. Likewise, birds migrating through the state will navigate along the best available habitat that allows them to navigate across the state with the least accumulative cost-distance.
- Resulting linkage rasters were sliced into 20 (5%) slices using an equal interval classification.
- The sliced raster was truncated at the value required to provide at least one linkage to each patch region. Cutoff values are:
  - basp_cor1.img = 20%
  - basp_cor2.img = 100%
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as

stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.

- Linkage maps were submitted for review and comments received (Appendix F).

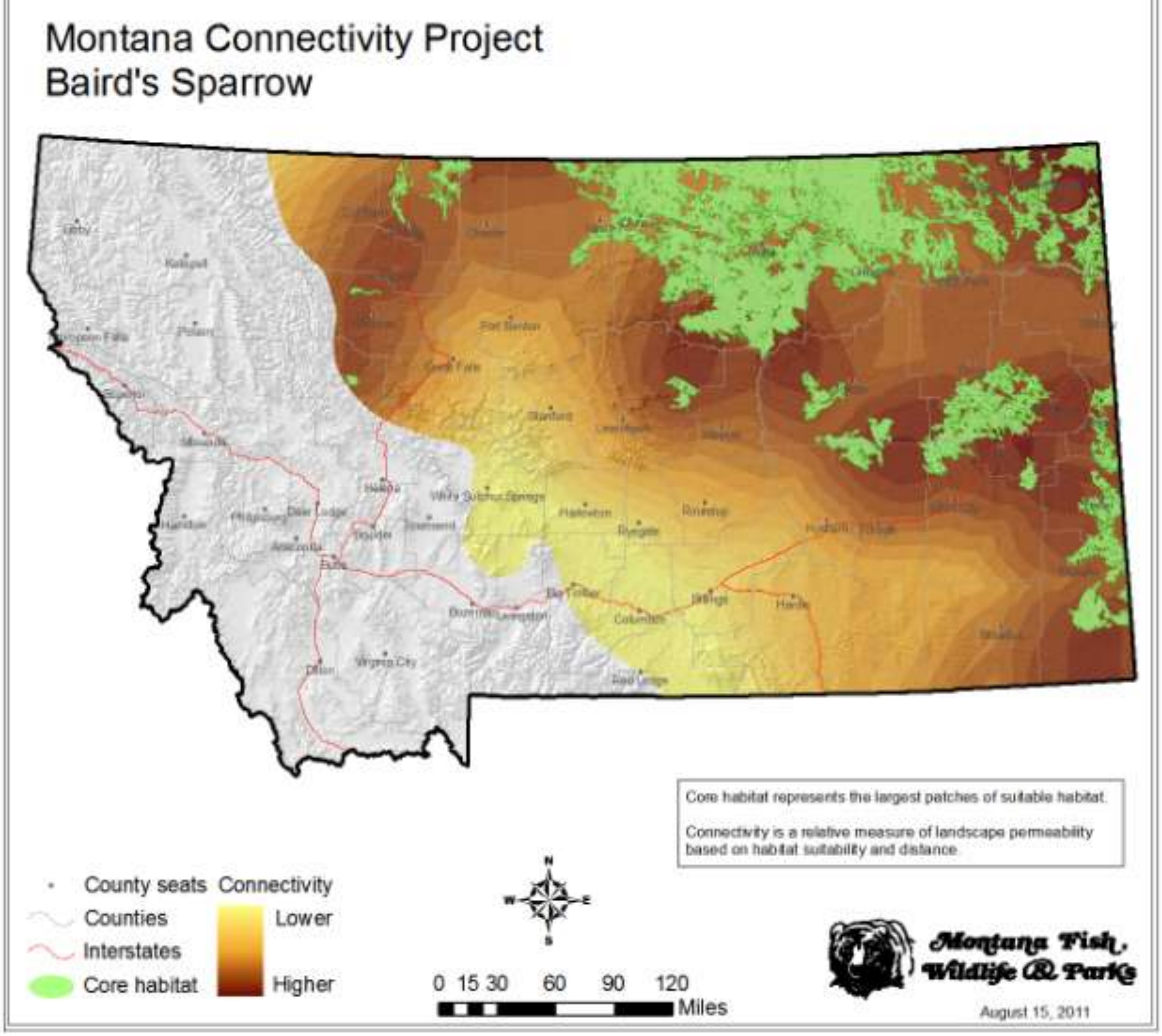


Figure 7. Baird’s Sparrow core habitat, stepping stones, and potential range/statewide landscape connectivity.

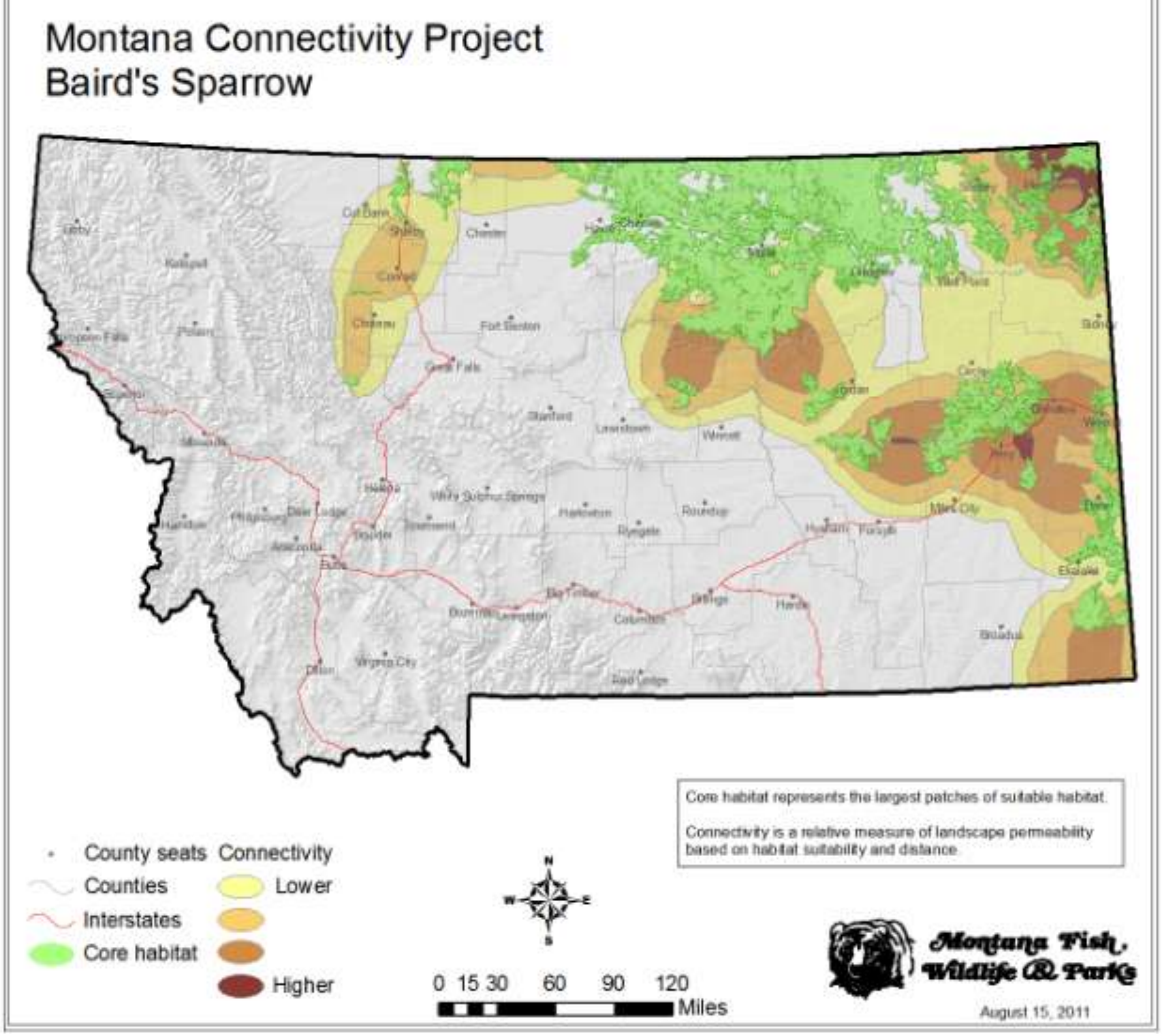


Figure 8. Baird's Sparrow core habitat, stepping stones*, and the minimum number of connectivity slices needed to connect all habitat cores. * NOTE: Stepping stones for Baird's Sparrow are not depicted on the above map, as those habitats identified as stepping stones, overlap almost all connectivity habitat.

3.1.2. Black Rosy-Finch (Leucosticte atrata)

Group: Avian

Ecosystem: Alpine

Type of connectivity: Seasonal, Range expansion/shift

Global/State Species of Concern Rank: G5/S3B

Confidence Rating: Core (NE) Connectivity (NE)

Figure 9. Black Rosy-Finch Range

Introduction: Black rosy- finch is an altitudinal migrant that breeds in Montana (Johnson 2002). Most black rosy finches move out of Montana during the winter (Johnson 2002). The black rosy- finch is commonly associated with Alpine and Sparse and Barren systems of Montana. It is occasionally associated with Forest and Woodland, and Shrubland, Steppe, and Savanna systems.

Black rosy- finch was added to the state SOC list in 2001 due to rarity and threats to habitat. Black rosy finch was selected as a focal species to represent alpine environments, due to the fact that it is a SOC with 38% of its global breeding range is in Montana. Special management actions are not currently requires.

Black rosy-finch serves as an umbrella species for white-tailed ptarmigan.

Section 1 – General Information
Supporting Information

- Black rosy-finch locations (see Section 2 for more information on location data).

Patch Delineation

- Black rosy-finch patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix that is interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having an average value greater than a given suitability threshold and within a 1600 hectare area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).
- Habitat patches may have been adjusted based on feedback from species experts.

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the percent area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
    - The habitat suitability model adequately represents landscape conditions preferred by Black rosy finch.
    - The parameters listed in Section 3 for patch development generally represent Black rosy finch behavior.
    - The selected habitat patches include the largest and "best" areas supporting Black rosy finch.
- Assumptions associated with connectivity analysis.
    - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
    - Black rosy finch move into and out of the state along a generally north-south movement path.
    - Black rosy finch migration paths balance traveling the shortest distance with remaining over suitable habitat.
    - Black rosy finch can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a map that was used for delineation of core areas and linkages.

- Habitat Suitability Model Inputs
    - Black rosy-finch locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than 400 meters. Only 4 locations were used for model training which often results in a weak model. However, this model compared well with the

deductive GAP model and provides the information needed for a cost surface.

- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
    - AUC for this model is not reliable due to the small sample size.

Section 3 – Habitat Patch Delineation

We used the Create Habitat Patch tool provided by CorridorDesigner (http://www.corridordesign.org) to determine areas that will be connected.

- Very little information exists on area needs for this species but breeding pairs use an area that is smaller than the finest resolution of the Maxent model (Johnson 2002). Contiguous habitat patches were identified using parameters that balanced the resolution of the maxent model and the resolution of the final connectivity map.
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 3
    - Perceptual distance (how far away is suitable habitat perceived) = 270 meters
    - Population patch size (minimum area needed to support a breeding pair) = 259 hectares. Based on the approximate area of a section which will be the resolution of the final map.

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the entire state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The additional process steps were applied:

- Habitat patches with nearest distance values ≤ 5 miles were assigned to the same region and treated as a single habitat patch complex for subsequent processing.
- Corridor rasters were generated between patch regions with "most likely" connections. For example if patch 2 was positioned between patches 1 and 3 and the best available

habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.

- The inverse of the habitat map (Maxent model) formed the cost surface.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review and comments received (Appendix F).

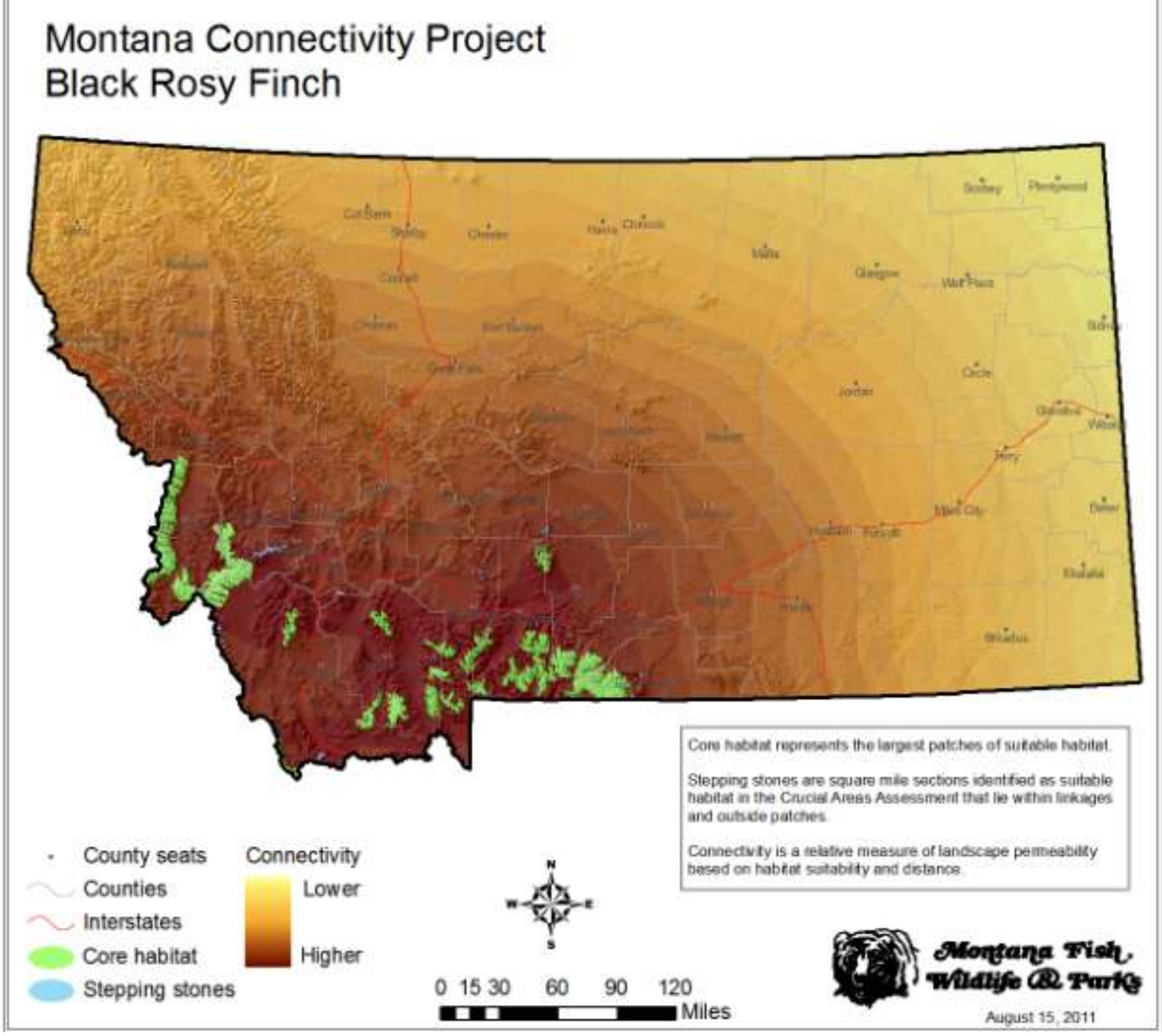


Figure 10. Black Rosy Finch Core habitat, stepping stones, and potential range/statewide landscape connectivity.

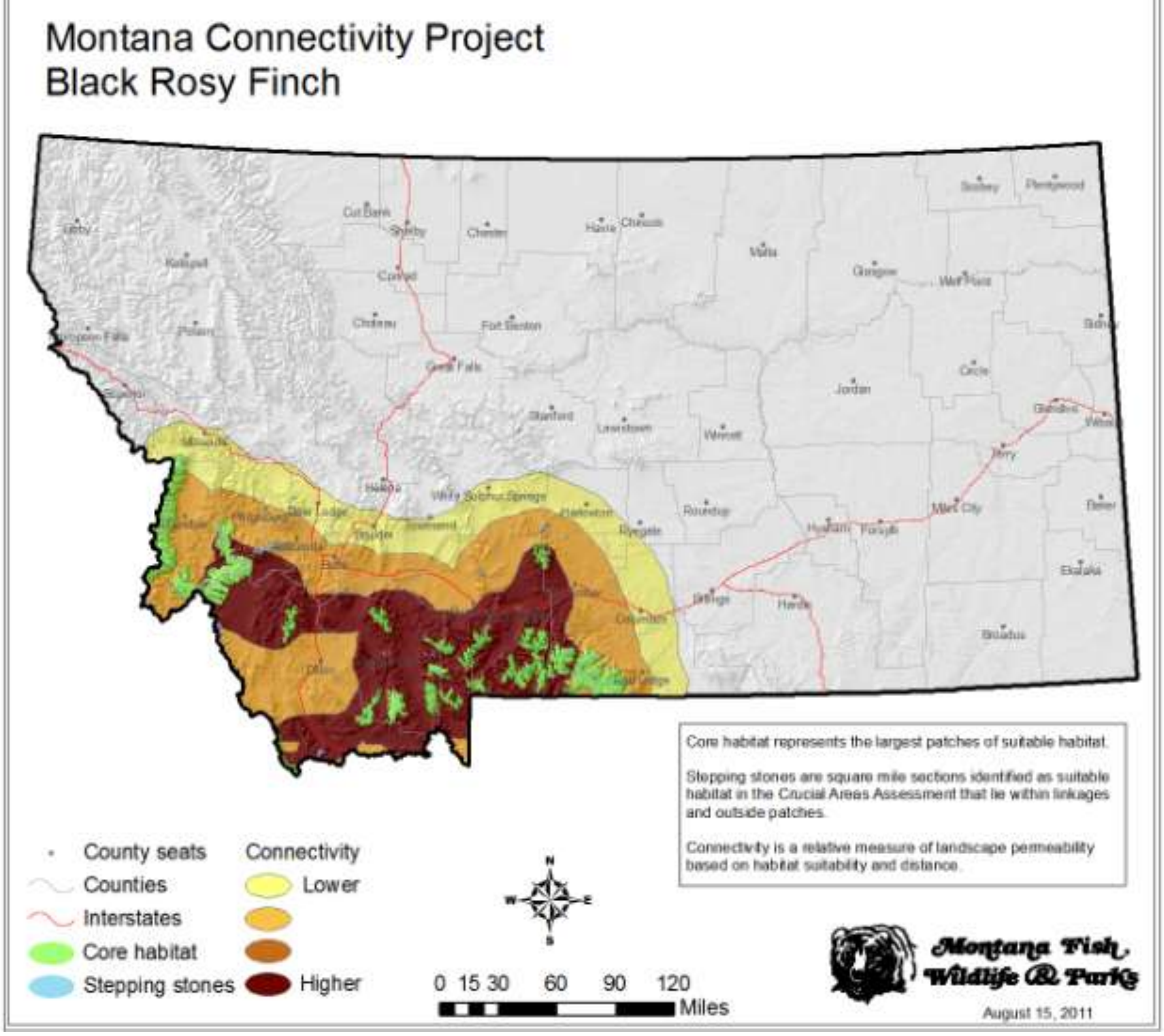


Figure 11. Black Rosy Finch core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.3. Black-tailed prairie dog (Cynomys ludovicianus)

Group: Mammal

Ecosystem: Shrub-steppe

Type of connectivity: Long-term

Global/State Species of Concern Rank: G4/S3

Confidence Rating: Core (High) Connectivity (Medium)

Figure 12. Black-tailed prairie dog Range

Introduction: Black-tailed prairie dog is a resident of Montana. It is commonly associated with Grassland, Shrubland, Steppe, and Savanna, and Sparse and Barren systems of eastern Montana. Black-tailed Prairie Dog colonies are found on flat, open grasslands and shrub/grasslands with low, relatively sparse vegetation. The most frequently occupied habitat in Montana is dominated by western wheatgrass, blue grama and big sagebrush (MFWP 2002).

Black-tailed prairie dog was added to the state SOC list in 1996 due to declining population trends, unknown viability of current colonies, and its key role in the life history of other species of concern. Black-tailed prairie dog was selected as a focal species to represent grassland environments, due to the fact that it is a SOC with 71% of Montana that is breeding range. Black-tailed prairie dog serves as an umbrella species for ferruginous hawk, mountain plover, swift fox, and white-tailed prairie dog.

Prairie dogs are managed under the Conservation Plan for Black-tailed and White-tailed Prairie Dogs in Montana (MFWP 2002). http://fwpiis.mt.gov/content/getitem.aspx?id=7341.
Please consult this plan for details concerning prairie dog management in Montana. Black-tailed Prairie Dogs are also classified as Vertebrate Pests by the Montana Department of Agriculture.

Section 1 – General Information
Supporting Information

- Black-tailed prairie dog locations (see Section 2 for more information on location data).

Patch Delineation

- Black-tailed prairie dog patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix interspersed with smaller areas of suitable habitat. (Figure XX)

- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive) and reduced to the extent of the range of the species (as identified by the MNHP).
- Habitat patches may have been adjusted based on feedback from species experts.

Connectivity Delineation

- Linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- A cost surface was generated by inversing the values in the habitat suitability model described above.
- Corridor values were calculated for all pair-wise patch combinations and combined to produce a composite least-cost surface for the entire analysis area.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by black-tailed prairie dogs.
  - The parameters listed in Section 3 for patch development generally represent black-tailed prairie dog behavior.
  - The selected habitat patches include the largest and “best” areas supporting black-tailed prairie dog.
- Assumptions associated with linkage delineation
  - Black-tailed prairie dogs are relatively constrained to suitable habitat and preferentially move within suitable habitat when dispersing.
  - No assumptions regarding dispersal distances within which “perfect” connectivity can be assumed were implied. All habitat patches were analyzed as discrete patches for connectivity analysis.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
  - Black-tailed prairie dog locations
    - A total of 1257 observations from the Point Observation Database, co-managed by Montana Fish, Wildlife, and Parks and The Montana Natural Heritage Program, were used for modeling. Observations from the POD database were limited to those with less than or equal to 400 meters of uncertainty. Twenty-five percent of the observations were withheld for testing the model.
- Landscape variables used for the Maxent model are documented in Appendix D. The layers used for modeling are all documented in Table 13 of the CAPS documentation. Parameters

were the same for all species. Layers used include: Elevation, Average Maximum Temperature, Land Cover Class, Geology, Slope, Average Minimum Temperature, and Distance From Streams.

- Habitat suitability model performance
    - Mean Area Under the Curve (AUC) for 30 replicate runs was 0.903. A model with no predictive power would have an AUC of 0.5 while a perfect model would have an AUC of 1.0 (Boyce et al. 2002).

Section 3 – Habitat Patch Delineation

We used the Create Habitat Patch tool provided by CorridorDesigner (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on a brief review of documents available on-line via Google searches.
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 0.471
    - On a 0-100 scaled maxent model, used a threshold of 47
    - Dispersal distance average = 2400 meter radius (Garrett and Franklin 1988). Koford (1958) reported emigration of nearly 6500m and Clark (1973) recorded white-tailed prairie dogs moving 2700m during emigration. Garrett and Franklin (1982) suggest maximum dispersal of 5000m. (See Technical note 431 - Harrell and Marks 2009.) Conservation of the black-tailed prairie dog, Edited by John L. Hoogland, 2006, Island Press.
    - Breeding patch size (minimum area needed to support breeding) -- used average colony size of 40 ha as per the Montana Field Guide (20-60 ha). Other sources indicate colony sizes that range to over 100 ha.
    - Population patch size (minimum area needed to support a population) = 200 ha (as per suggestion in the CorridorDesigner patch tool).
    - The resulting patches data set was clipped to the extent of the state of Montana and then to the extent of the range map provided by MNHP.
    - The 20 largest patches were selected and used to represent the major areas supporting Black-tailed prairie dogs.

Methods used to create input\output data:

- Created maxent grid using asciigrid command in ArcGrid; multiplied grid by 1000 to rescale values from 0-.999 to 0-999.xxx; integerized grid; extracted by mask the maxent model using the species range map.
- Patches were created using CorridorDesigner - Moving window was defined as Circle using Map units (meters).
- Calculated area field (in sq m); sorted by area in descending order; selected the top 20 records.

- **Note:** patches extend beyond the extent of the input data set (in this case the Maxent model grid limited to the species range). Thus, it is necessary to clip the patches generated by CorridorDesigner to the state boundary.

    - Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generate cost-distance surfaces for each input source layer.
- Generate corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the entire state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

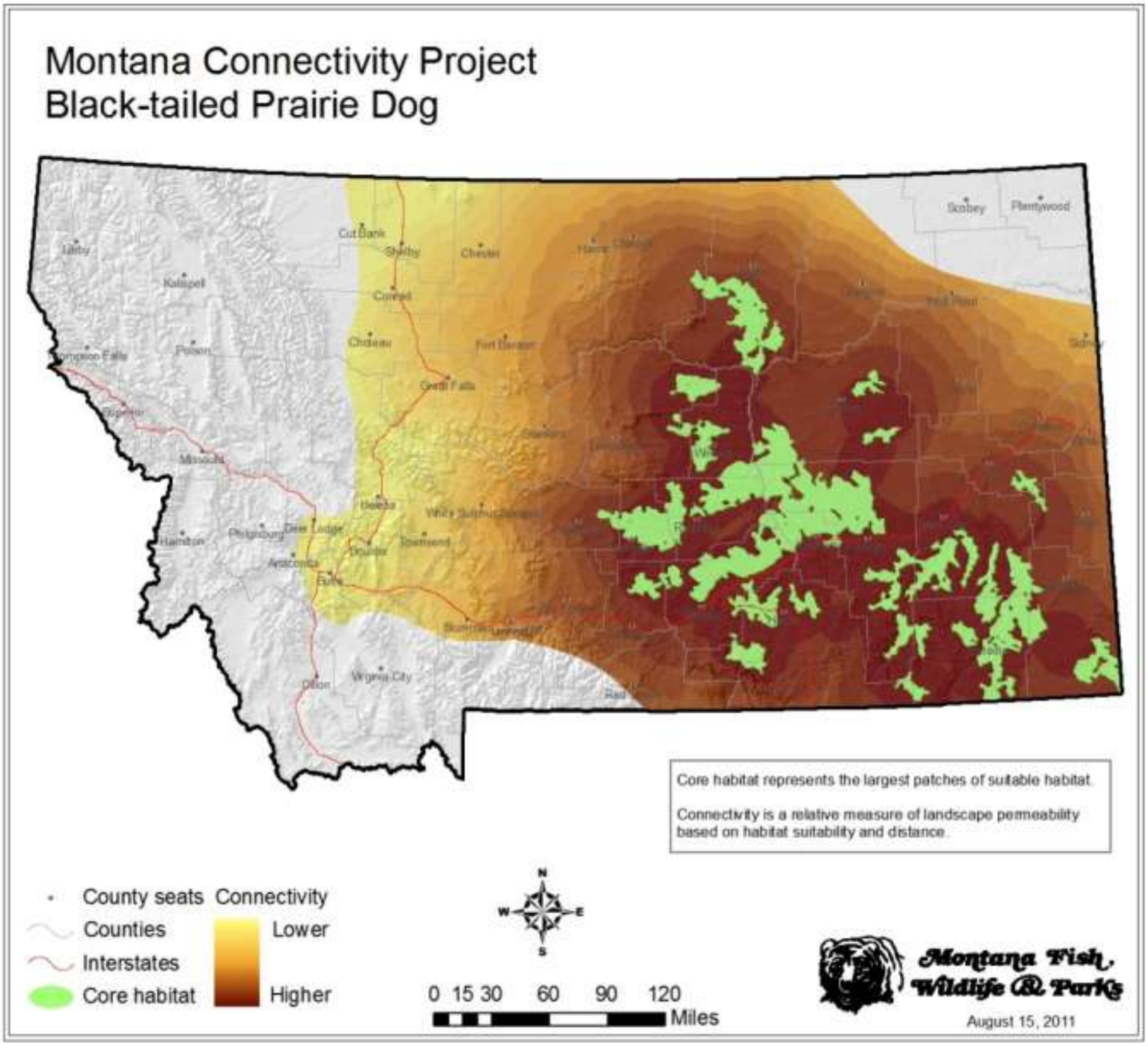


Figure 13. Black-tailed Prairie Dog Core habitat and potential range/statewide landscape connectivity.

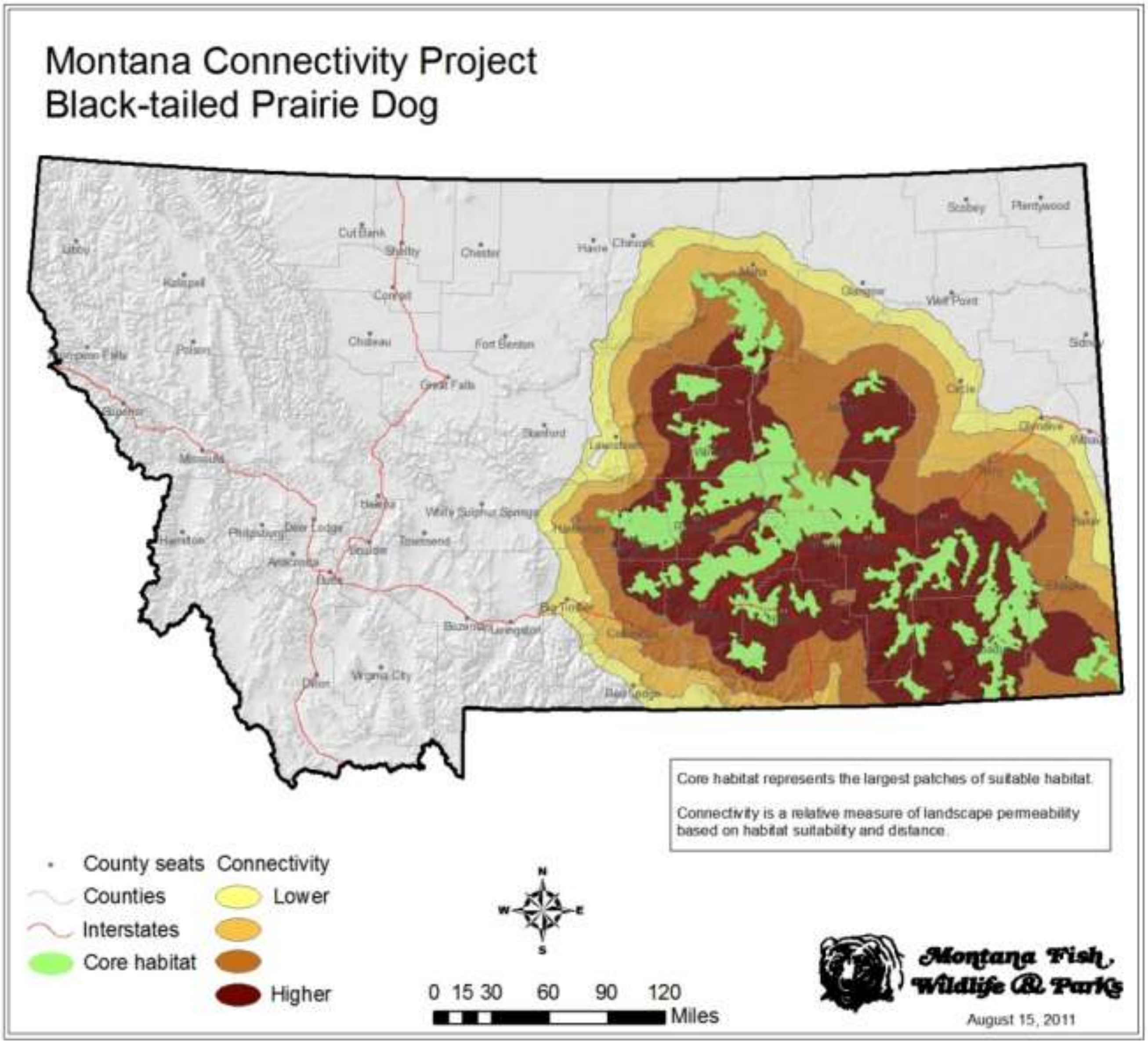


Figure 14. Black-tailed Prairie Dog Core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.4. Cassin's Finch (Carpodacus cassinii)

Group: Avian

Ecosystem: Forest Specialist

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G5/S3

Confidence Rating: Core (NE) Connectivity (NE)

Figure 12. Cassin's Finch Range

Introduction: Cassin's finch is a year-round resident of Montana. It is commonly associated with forest and soodland systems west of the Continental Divide. Cassin's finch occurs in every major forest type and timber-harvest regime in Montana, including riparian cottonwood, but is especially common in ponderosa pine and post fire forests; they occur less often in lodgepole pine, sagebrush, and grassland (Manuwal 1983a, Hutto and Young 1999). Cassin's finches are one of the more abundant birds in early post fire conifer forests, where their numbers can increase significantly regardless of fire severity; attraction to these sites may result from increased seed resources. They also are attracted to harvested forests and stands where post fire salvage logging has occurred, although these habitats may serve as ecological traps (Hutto 1995, Hutto and Young 1999, Smucker et al. 2005).

Cassin's finch was added to the state SOC list in 2008 due to declining population trends and threats to conifer forest habitats from insects and fire. Given their occurrence in burned and harvested forests, the population declines that have been identified recently are difficult to explain. Cassin's finch is a seasonal migrant. It was selected as a focal species to represent conifer forest environments, due to the fact that it is a SOC with 62% of Montana serving as breeding range. Cassin's finch has not been identified as an umbrella species.

No management activities specific to Cassin's Finch are currently occurring in Montana..

Section 1 – General Information
Supporting Information

- Cassin's finch locations (see Section 2 for more information on location data).

Patch Delineation

- Cassin's finch patches delineated for this project represent the 25 largest areas of suitable habitat separated by a less suitable matrix interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches

having an average value greater than a given suitability threshold and within a 100 hectare area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).

- Habitat patches may have been adjusted based on feedback from species experts.

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the percent area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by Cassin's finch.
  - The parameters listed in Section 3 for patch development generally represent Cassin's finch behavior.
  - The selected habitat patches include the largest and "best" areas supporting Cassin's finch.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influenced by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
  - Cassin's finch move into and out of the state along a generally north-south movement path.
  - Cassin's finch migration paths balance traveling the shortest distance with remaining over suitable habitat.
  - Cassin's finch can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a map that was used for delineation of core areas and linkages. This map was also used for the Crucial Areas Assessment.

- Habitat Suitability Model Inputs
  - Cassin's finch locations
    - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those

associated with breeding behavior and with a spatial uncertainty smaller than 400m. A total of 767 locations were used for model training and 255 locations were used for model testing.

- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
    - AUC from test data = 0.897. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation
We used the Create Habitat Patch tool provided by CorridorDesigner (http://www.corridordesign.org) to determine areas that will be connected.

- Very little information exists on area needs for this species but breeding pairs use an area that is smaller than the finest resolution of the Maxent model (Hahn 1996). Contiguous habitat patches were identified using parameters that balanced the resolution of the maxent model and the size of the final patches.
- Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 34
- Perceptual distance (how far away is suitable habitat perceived) = 270 meters
- Population patch size (minimum area needed to support a population) = 100 hectares. The 25 largest patches were used to represent the major areas supporting Cassin's finch.

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 25 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generate cost-distance surfaces for each input source layer.
- Generate corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the entire state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.
The additional process steps were applied:

- Habitat patches with nearest distance values ≤ 5 miles were assigned to the same region and treated as a single habitat patch complex for subsequent processing.
- Corridor rasters were generated between patch regions with "most likely" connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Additional corridors were calculated to connect to the boundary of the state limited to the portion that coincides with the range map of the species and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow the species to move across state boundaries to at least one (and quite often more) patch region(s).
- Two data sets were used to create the cost surface for this species: (1) the inverse of the habitat map (Maxent model) and (2) the Montana mountains grid. The MT mountains layer was adjusted so that any areas identified by the raw patch map were subset out and assigned a value of zero. The point was to set to no cost any area that the patch model indicated as "habitat" for the species.
- The MT mountains layer was assigned a multiplier value of 0.5.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review and comments received (Appendix F).

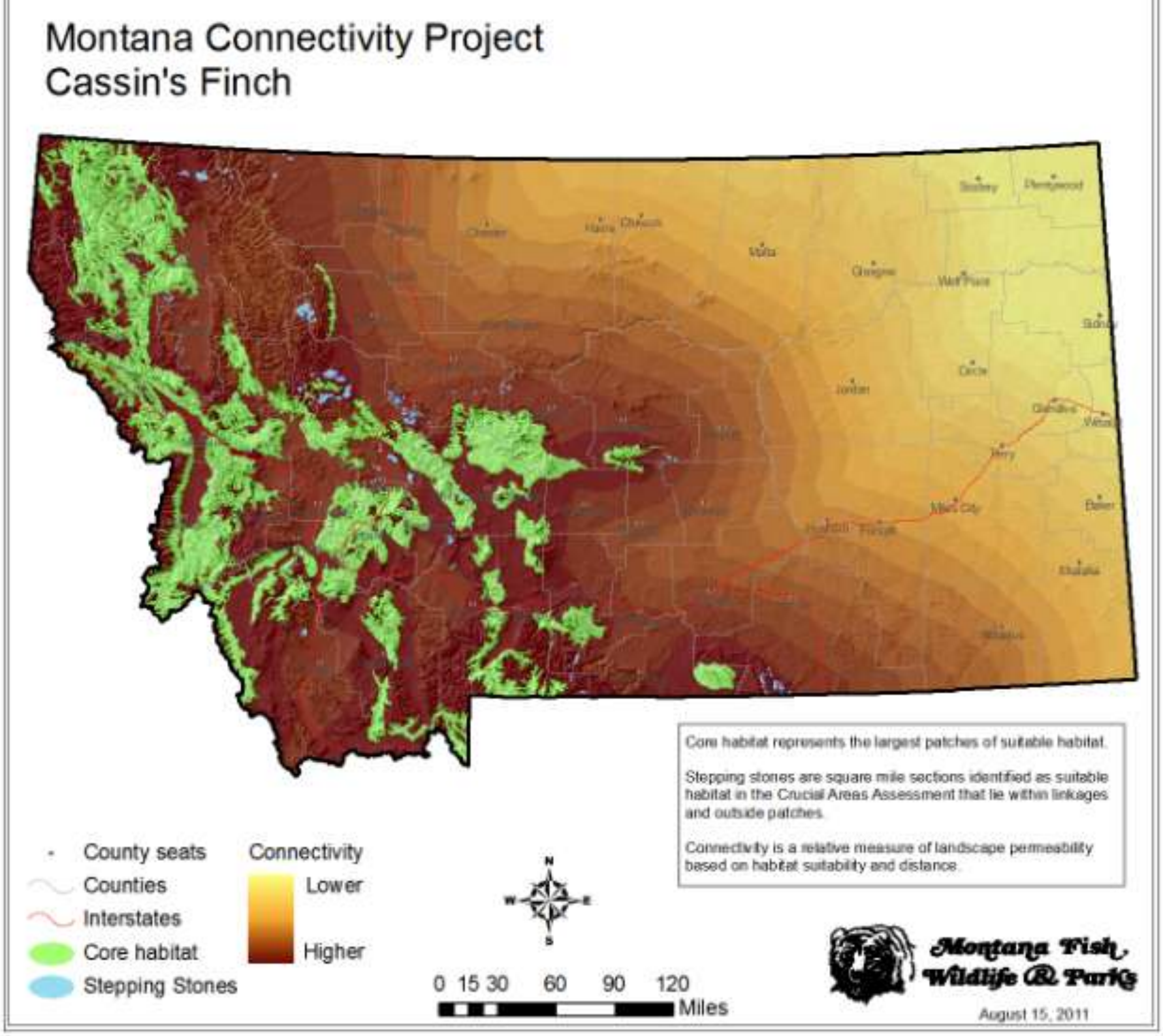


Figure16. Cassin's Finch core habitat, stepping stones, and potential range/statewide landscape connectivity.

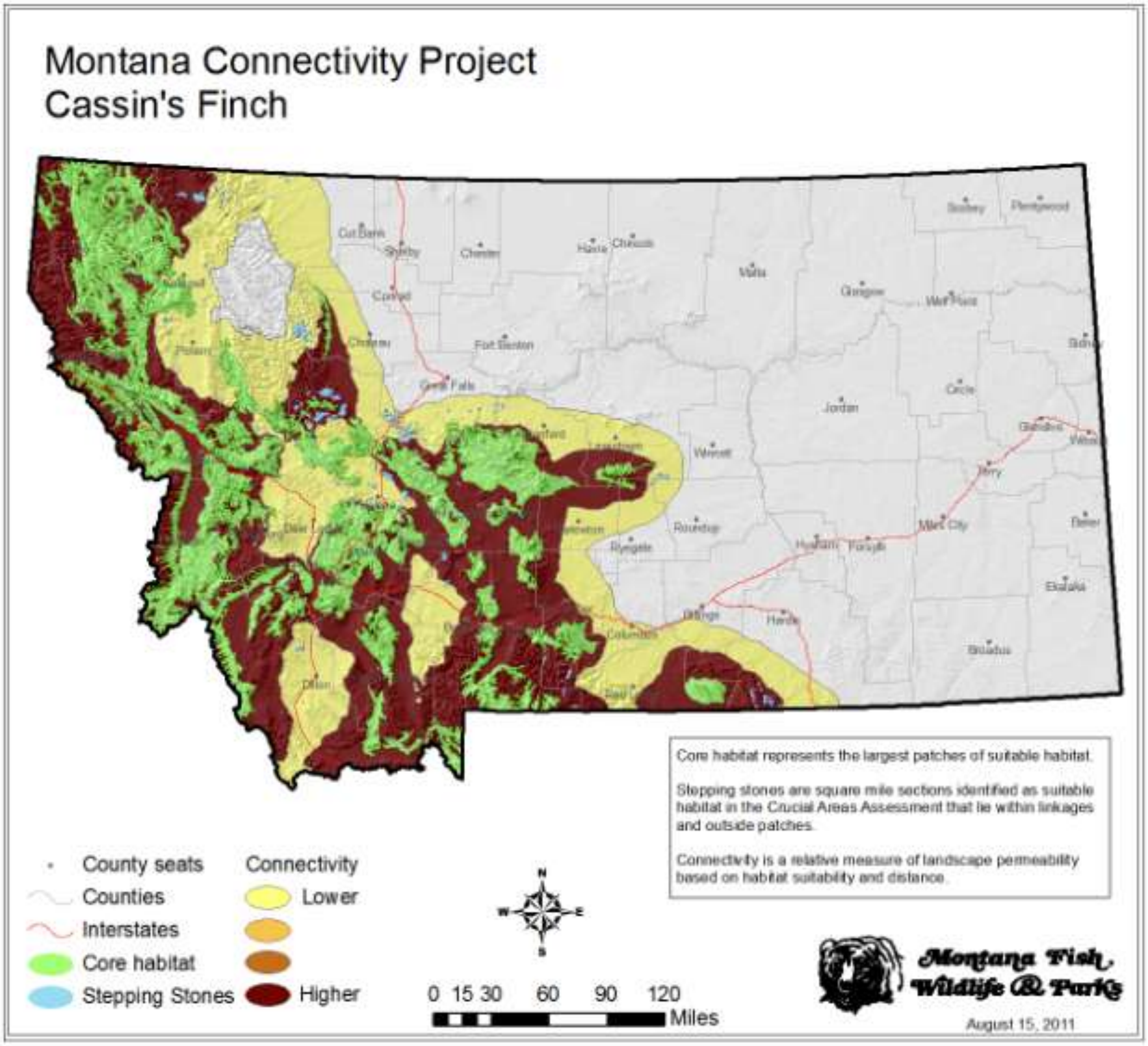


Figure 17. Cassin's Finch core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.5. Clark's Nutcracker (Nucifraga columbiana)

Group: Avian

Ecosystem: Forest Specialist

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G5/S3

Confidence Rating: Core (Low) Connectivity (NE)

Figure 18. Clark's Nutcracker Range

Introduction: Clark's nutcracker is a year-round resident of Montana. It is commonly associated with Forest and Woodland, Grassland, and Shrubland, Steppe, and Savanna systems. Nutcrackers in Montana typically occupy conifer forests dominated by whitebark pine at higher elevations and ponderosa pine and limber pine along with Douglas firs at lower elevations, relying largely on seeds of these species for food (Saunders 1921, Mewaldt 1956, Giuntoli and Mewaldt 1978). They often are seen above treeline in alpine meadows or flying among drainages (Weydemeyer 1931, Johnson 1966, Pattie and Verbeek 1966).

Clark's nutcracker was added to the state SOC list in 2008 due to declining population trends and threats to conifer forest habitats due to disease, insects, and fire. Clark's nutcracker may be nomadic but is not migratory in the typical sense. It was selected as a focal species to represent conifer forest environments, due to the fact that it is a SOC with 84% of Montana serving as breeding range. Clark's nutcracker has been identified as an umbrella species for grizzly bear, pinyon jay, and brown creeper.

No management activities specific to Clark's nutcracker are currently occurring in Montana. Clark's nutcracker is dependent on conifer seeds, particularly pine seeds. Loss of pines (whitebark, limber, ponderosa) to fire, disease, and bark beetle outbreaks could impact populations; management activities promoting the health of pines will benefit nutcrackers.

Section 1 – General Information
Supporting Information –

- Clark's nutcracker locations (see Section 2 for more information on location data).

Patch Delineation

- Clark's nutcracker patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix that is interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having an average value greater than a given suitability threshold within a 2500 hectare

area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the percent area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by Clark's nutcracker.
  - The parameters listed in Section 3 for patch development generally represent Clark's nutcracker behavior.
  - The selected habitat patches include the largest and "best" areas supporting Clark's nutcracker breeding pairs.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influenced by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
  - Clark's nutcrackers are year-round residents that are semi-nomadic, responding to seasonal and inter-annual spatial variability of food resources.
  - Clark's nutcrackers movement paths balance traveling the shortest distance with remaining over suitable habitat.
  - Clark's nutcrackers can easily move within 5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment - Complete

A Maxent (inductive) model was used to develop a map that was used for delineation of core areas and linkages. Model output is the average of 30 model runs using a jackknife sampling approach.

- Habitat Suitability Model Inputs
  - Clark's nutcracker locations
    - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than

400m. Locations obtained from structured surveys conducted in the Upper Clark Fork Basin in 2009 were also included. A total of 2219 locations were used for model training and 77 locations were used for model testing.

- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
    - AUC from test data = 0.952. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation

We used the Create Habitat Patch tool provided by CorridorDesigner (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on Clark's nutcracker literature (Tomback 1998).
    - o Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 3
    - o Perceptual distance (how far away is suitable habitat perceived) = 1500 meters
    - o Breeding patch size (minimum area needed to support a breeding pair) = 2500 hectares. Based on a small home range size observed for this species.
- Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 21 patches, though one patch is an infill patch.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.

- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review and comments received (Appendix F).

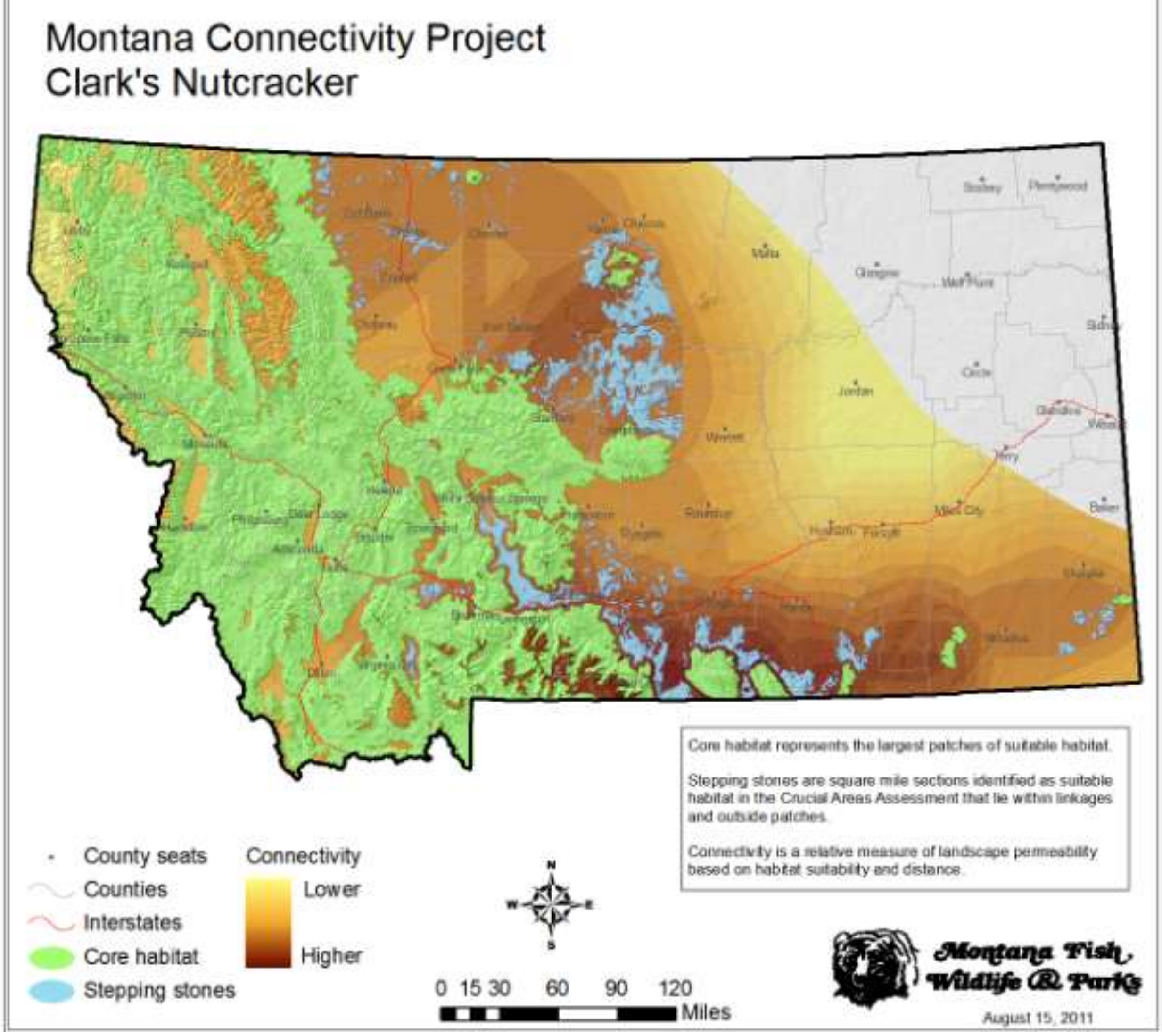


Figure19. Clark's Nutcracker core habitat, stepping stones, and potential range/statewide landscape connectivity.

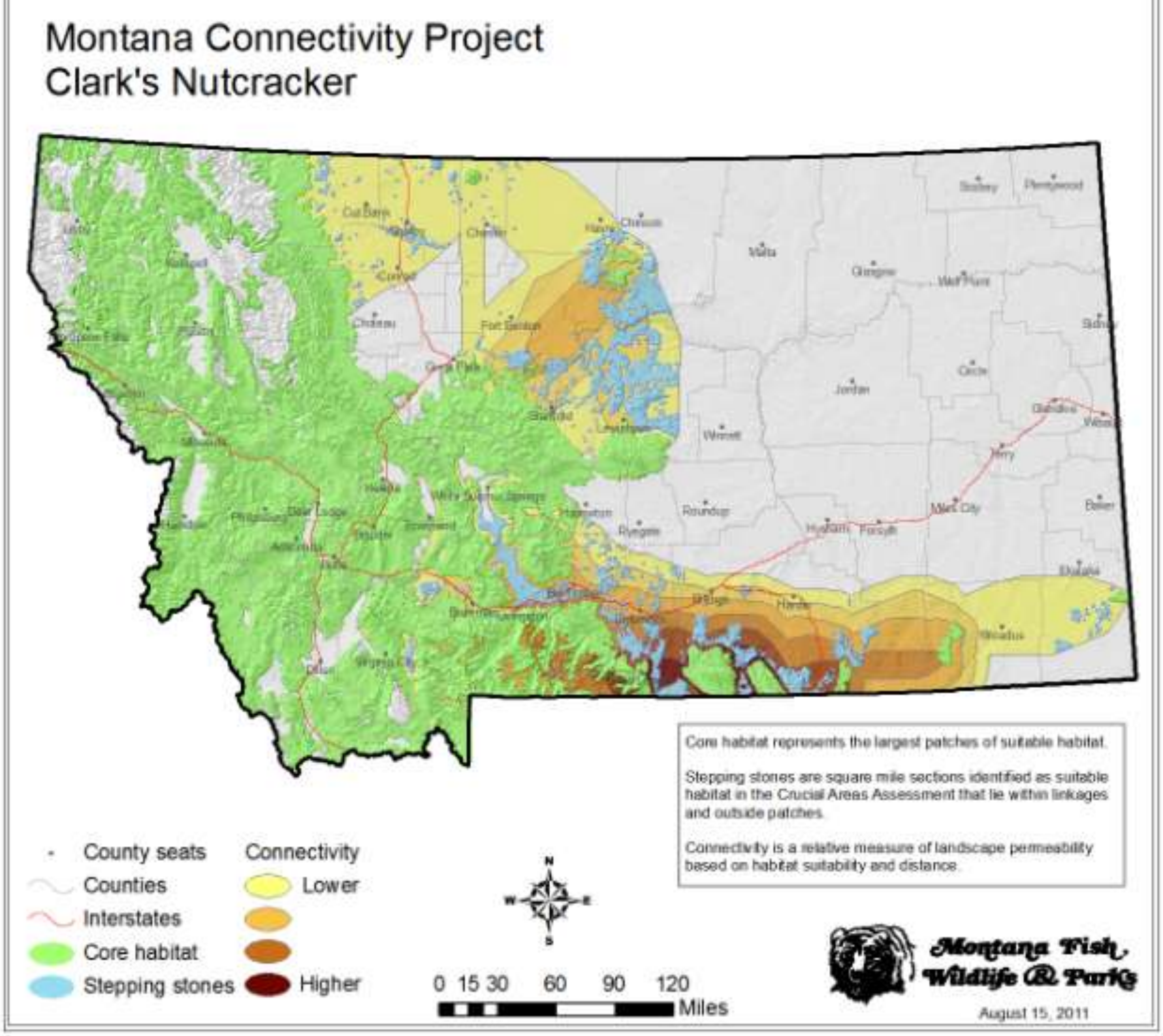


Figure 20. Clark's Nutcracker Core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.6. Ferruginous Hawk (Bueto regalis)

Group: Avian

Ecosystem: Shrub-steppe

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G4/S3B

Confidence Rating: Core (Low) Connectivity (Low)

Figure 21. Ferruginous Hawk Range

Introduction: Ferruginous hawk is a seasonal migrant that breeds in Montana. It is commonly associated with Forest and Woodland, Grassland, and Shrubland, Steppe, and Savanna, and Sparse and Barren systems. Ferruginous hawks in Montana typically occupy open grassland and sage steppe environments.

Ferruginous hawk was historically added to the state SOC list, but the date and proximate reasons are undocumented. Ferruginous hawk was selected as a focal species to represent conifer forest environments, due to the fact that it is a SOC with 95% of Montana serving as breeding range. Ferruginous hawk has been identified as an umbrella species for Swanson's hawk and rough-legged hawk.

Although no active management is currently in place for Ferruginous hawks in Montana, other management plans do take this species into account. For example, Black-tailed prairie dog towns in the Judith-Valley-Phillips Resource Management Area are currently managed to help provide habitat for Ferruginous hawks (Grensten 2002) as they use the dog towns for food and shelter. Ferruginous hawks seem to accept and readily use artificial nest structures when placed in areas where populations have declined or where habitats lack suitable nest sites (Olendorff 1993). This practice would likely benefit Ferruginous hawks in eastern Montana where nesting is primarily on the ground and nest structures would reduce predation (Wittenhagen 1992).

Section 1 – General Information
Supporting Information –

- Ferruginous hawk locations (see Section 2 for more information on location data).

Patch Delineation

- Ferruginous hawk patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix that is interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having an average value greater a given suitability threshold within a 313 hectare area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
    - A cost surface was generated by inversing the values in the habitat suitability model described above and reducing costs by half over mountainous areas.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the percent area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
    - The habitat suitability model adequately represents landscape conditions preferred by Ferruginous hawk.
    - The parameters listed in Section 3 for patch development generally represent Ferruginous hawk behavior.
    - The selected habitat patches include the largest and “best” areas supporting Ferruginous hawk breeding pairs.
- Assumptions associated with connectivity analysis.
    - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
    - Ferruginous hawks move into and out of the state along a generally north-south movement path.
    - Ferruginous hawks take advantage of thermals over mountain uplifts as do other raptors.
    - Ferruginous hawk migration paths balance traveling the shortest distance with remaining over suitable habitat.

    - Ferruginous hawks can easily move within 5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment - Complete
A Maxent (inductive) model was used to develop a map that was used for delineation of core areas and linkages. This map was also used for the Crucial Areas Assessment.

- Habitat Suitability Model Inputs
    - Ferruginous hawk locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than 400m. A total of 567 locations were used for model training and 189 locations were used for model testing.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
    - AUC from test data = 0.947. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation
We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on Ferruginous hawk literature (Dechant et al 2002).
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 5
    - Perceptual distance (how far away is suitable habitat perceived) = 1732 meters
    - Breeding patch size (minimum area needed to support a breeding pair) = 313 hectares. Based on smallest home range size observed for this species.

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.

- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with "most likely" connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated between each of the border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow birds to migrate from the state boundaries to each patch region.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Linkage maps were submitted for review and comments received (Appendix F).

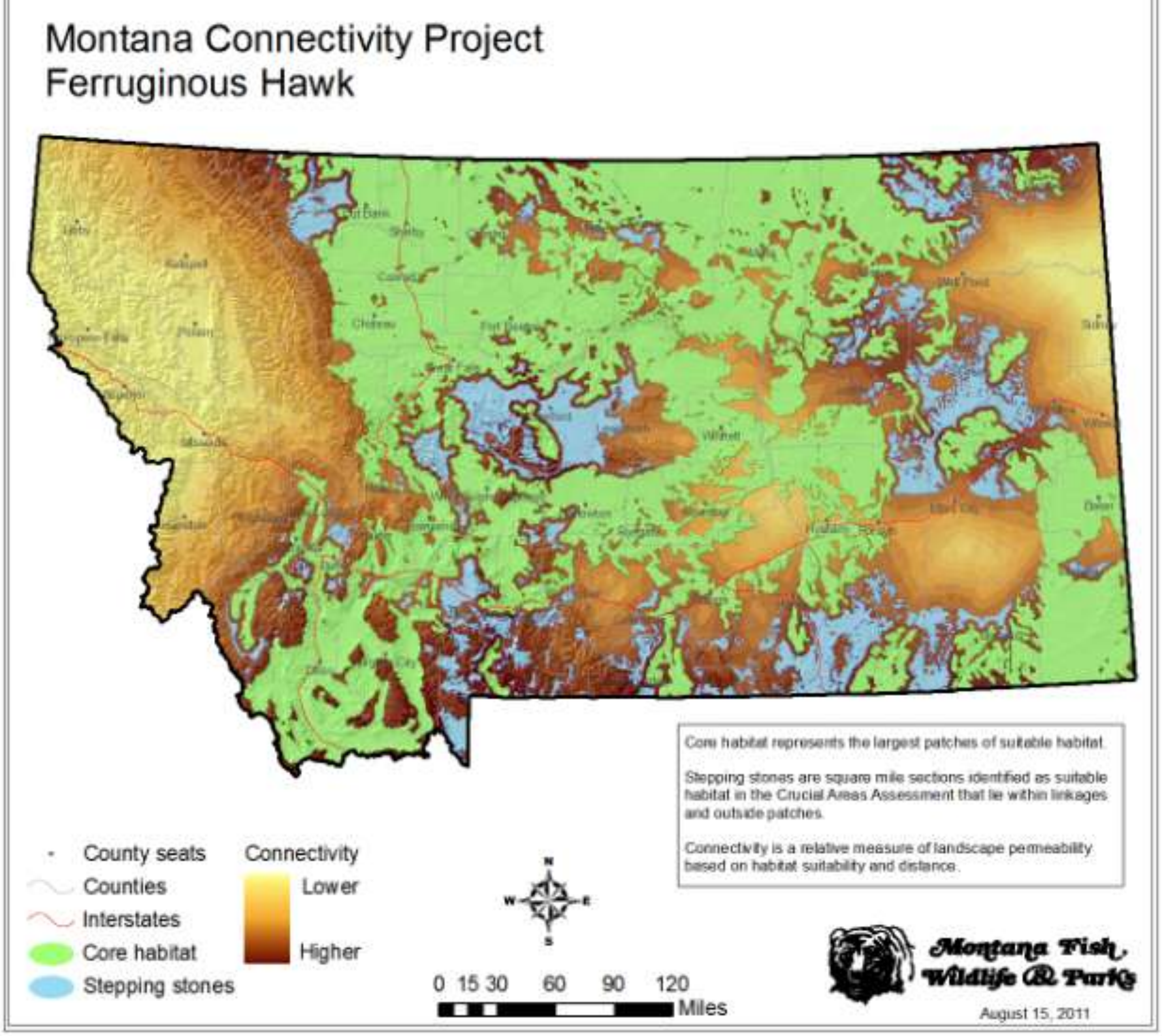


Figure22. Ferruginous Hawk core habitat, stepping stones, and potential range/statewide landscape connectivity.

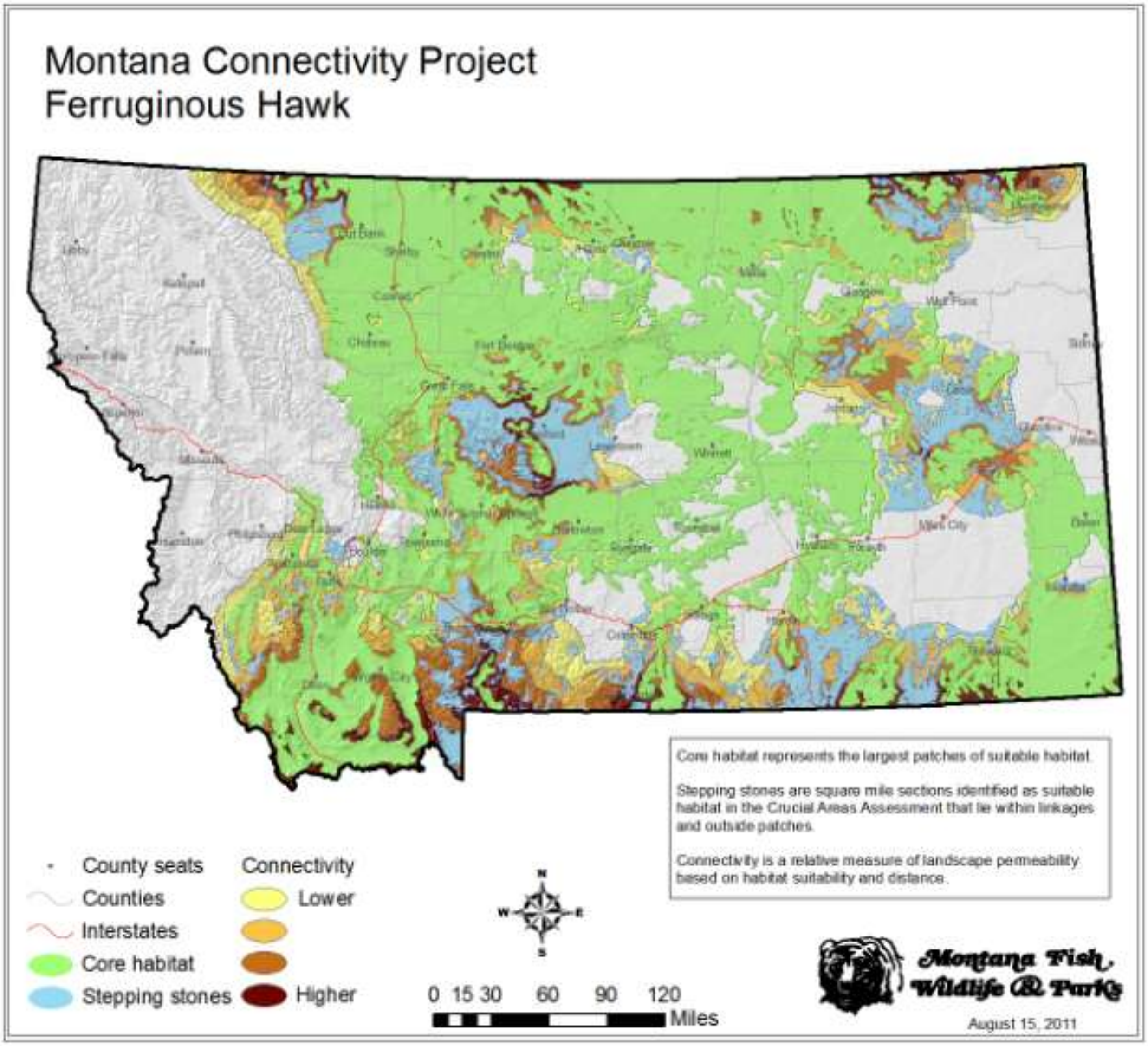


Figure23. Ferruginous Hawk core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.7. Greater Sage-Grouse (Centrocercus urophasianus)

Group: Avian

Ecosystem: Shrub-steppe

Type of connectivity: Within seasonal/seasonal

Global/State Species of Concern Rank: G4/S2

Confidence Rating: Core (High) Connectivity (Medium)

Figure 24. Greater Sage-Grouse Range

Introduction: Greater Sage- grouse is a year-round resident of Montana. It is commonly associated with Shrubland, Steppe, and Savanna systems and occasionally associated with Forest and Woodland, Grassland, and Sparse and Barren systems.

Greater Sage- grouse was added to the state SOC list in 2004 due to declining population trends and threats to habitat. It was selected as a focal species to represent sage-steppe environments, due to the fact that it is a SOC with 75% of Montana serving as breeding range. Greater Sage Grouse has been identified as an umbrella species for sage thrasher, sage sparrow, Brewer's sparrow, sharp-tailed grouse, and pygmy rabbit.

On March 5, 2010, the U.S. Fish and Wildlife Service determined that the Greater Sage-Grouse warrants protection under the Endangered Species Act, but that listing the species under the Act is precluded by the need to address other listing actions of a higher priority. Additional information on the species' management can be found on the U.S. Fish and Wildlife Service's species account: http://www.fws.gov/mountain-prairie/species/birds/sagegrouse/

Section 1 – General Information
Supporting Information –
Greater Sage-grouse Leks, Lek Areas and Core Areas produced by MFWP were used as reference information for this species.

Patch Delineation - See section 2 for more details on habitat quality mapping and section 3 for more information on patch delineation.

- Patches (Core Areas) represent large blocks of suitable habitat supporting the highest densities of displaying males.
- Patch delineations were reviewed and refined by biologist using a habitat suitability model showing areas of > 10% suitability, and a model denoting the areas supporting the top 25% of breeding males.

- Small patches and large blocks of intact habitat not supporting high male numbers were eliminated during biologist review.
- Patches outside of Montana may need to be identified, depending on connectivity options below.

Connectivity Delineation - See section 4 for more information on connectivity analysis.
- Linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Corridor values were calculated for all pair-wise patch combinations and combined to produce a composite least-cost surface for the entire analysis area.

Assumptions:
- Assumptions associated with habitat and patch delineation
  - Lek locations adequately represent areas of suitable habitat.
- Assumptions associated with connectivity analysis.
  - Core areas contain suitable habitat and have no significant barriers to movement.
  - Habitat selection is the same for core habitat patches and connectivity habitat.
  - Sage-grouse choose to move between habitat patches along areas of suitable terrestrial habitat.
  - Layers used for the habitat quality assessment represent all potential barriers to sage grouse movement.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to generate a layer of habitat suitability that was subsequently used to delineate core areas and connectivity.
- Modeling Technique: MaxEnt
  - Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
    - Inputs: 1177 Locations
    - Primarily Leks - Spatially unique locations used to train model;
  - Locations accurate to within 400 meters
  - Model Run: 2008
  - AUC from test data = 0.917. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation

Habitat patches (core areas) were delineated to identify areas to be connected, using the following process:
- Using the habitat suitability model, outlines were drawn around areas with > 10% suitability. Smoothing was used to reduce isolated grid cells by selecting grid cells with > 75% of the surrounding 1000 acres was > 10% suitability.

- A kernel density estimator was used to delineate areas that supported the highest 25% of males attending leks statewide.
    - Point Layer – Leks2008
    - Weights – Average MaxMalesLast10years
    - Scaling factor – Default 1,000,000
    - Kernel – Default Bivariate Normal
    - Single Parameter Smoothing – 10,000
    - Cell Size – 500m
- Contiguous predicted occurrence areas that overlapped highest male density were highlighted.
- Area biologists added, eliminated and adjusted core area boundaries based upon professional expertise.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.
- Corridor rasters were generated between core habitat patches. All possible pair-wise combinations were calculated.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.

Linkage maps were submitted for review and comments received (Appendix F).

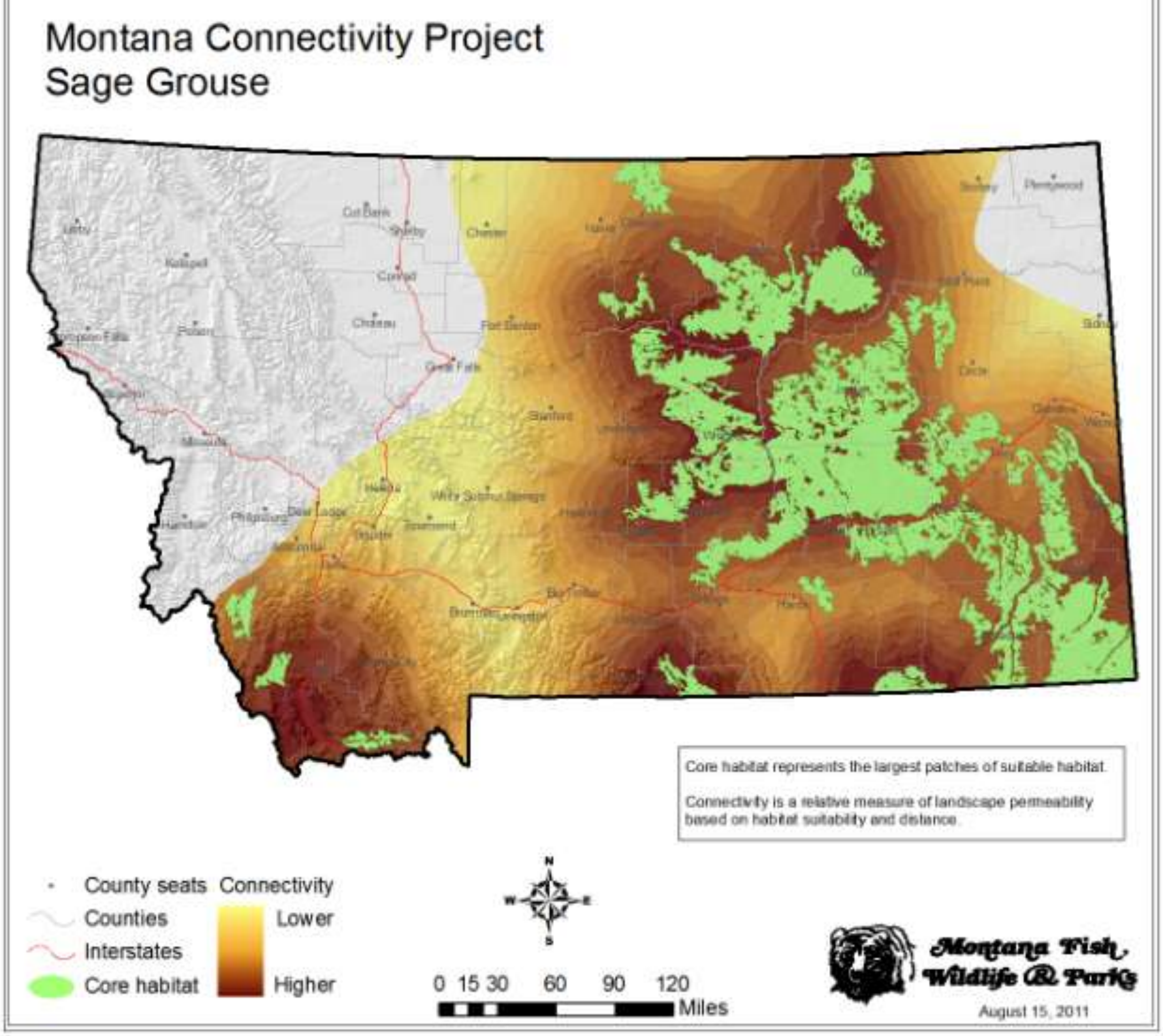


Figure 25. Greater Sage-Grouse core habitat and potential range/statewide landscape connectivity.

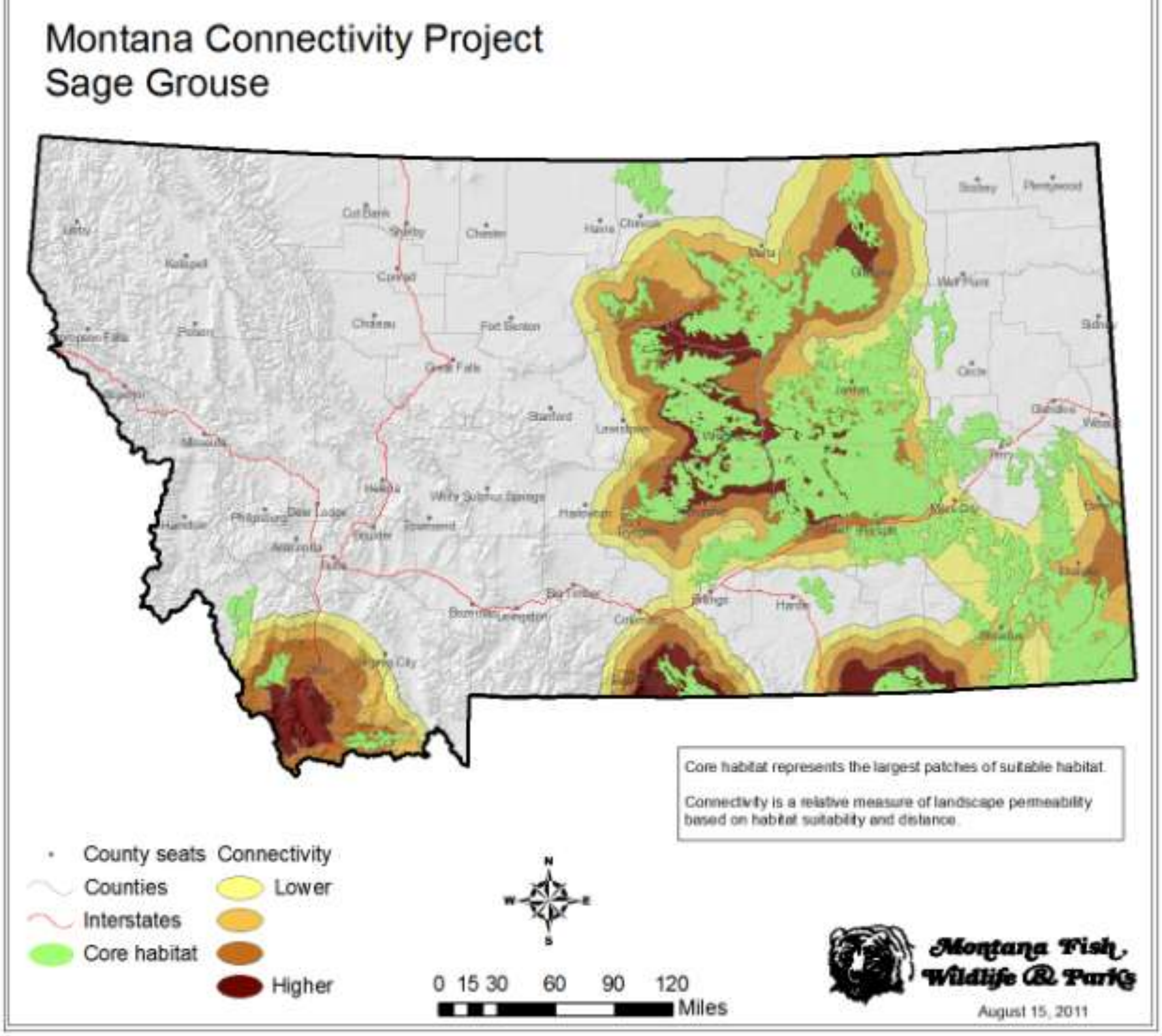


Figure 26. Greater Sage-Grouse core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.8. Long-billed Curlew (Numenius Americanus)

Group: Avian

Ecosystem: Grassland/Shrub

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G5/S3B

Confidence Rating: Core (Medium) Connectivity (NE)

Figure 27. Long-billed Curlew Range

Introduction: Long-billed Curlew is a seasonal migrant that breeds in Montana. It is commonly associated with Grassland, Shrubland, Steppe, and Wetland / Riparian systems. Long-billed Curlew in Montana typically occupy open short and mixed grass grassland environments.

Long-billed Curlew was added to the state SOC list in 2004 due to an evaluation of threats faced by the species. Long-billed Curlew was selected as a focal species to represent grassland environments, due to the fact that it is a SOC with 100% of Montana serving as breeding range. Long-billed Curlew has been identified as an umbrella species for Grasshopper Sparrow and Bobolink.

Section 1 – General Information
Supporting Information –

- Long-billed curlew locations (see Section 2 for more information on location data).

Patch Delineation

- Long-billed curlew patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix that is interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having an average value greater than a given suitability threshold within a 6 hectare area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).
- Habitat patches may have been adjusted based on feedback from species experts.

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.

- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the % area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by Long-billed curlew.
  - The parameters listed in Section 3 for patch development generally represent Long-billed curlew behavior.
  - The selected habitat patches include the largest and "best" areas supporting Long-billed curlew.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
  - Long-billed curlews move into and out of the state along a generally north-south movement path.
  - Long-billed curlew migration paths balance traveling the shortest distance with remaining over suitable habitat.
  - Long-billed curlews can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a map that was used for delineation of core areas and linkages. Model output is the average of 30 model runs using a jackknife sampling approach.

- Habitat Suitability Model Inputs
  - Long-billed curlew locations
    - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than 400m. Locations obtained from structured surveys conducted in the Upper Clark Fork Basin in 2009 were also included. Approximately 415 locations were used for model training and 15 locations were used for model testing for each model run.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.

- Habitat suitability model performance
    - AUC from test data = 0.937. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation

We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on Long-billed curlew literature (Dugger and Dugger 2002).
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 3
    - Perceptual distance (how far away is suitable habitat perceived) = 200 meters
    - Breeding patch size (minimum area needed to support a breeding pair)
        - First effort = 6 hectares Based on a small male territories observed for this species. Compare with comments from Ryan Rauscher in reviewer comments -- mean of 14 ha, up to 20 ha, with a 500 m buffer.
        - Second effort -- threshold = 2; perceptual distance = 1100 m; breeding patch size = 14 ha; population patch size = 70 ha
        - Third effort -- threshold = 1; perceptual distance = 2800 m; breeding patch size = 20 ha; population patch size = 100 ha
  - Population patch size (minimum area needed to support a population) = Undocumented

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with “most likely” connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated between the north and south border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow the species to move across state boundaries to at least one (and quite often more) patch region(s).
- Two data sets were used to create the cost surface for this species: (1) the inverse of the habitat map (Maxent model) and (2) the Montana mountains grid. The MT mountains layer was adjusted so that any areas identified by the raw patch map were subset out and assigned a value of zero. The point was to set to no cost any area that the patch model indicated as "habitat" for the species.
- The MT mountains layer was assigned a multiplier value of 0.5.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review and comments received (Appendix F).

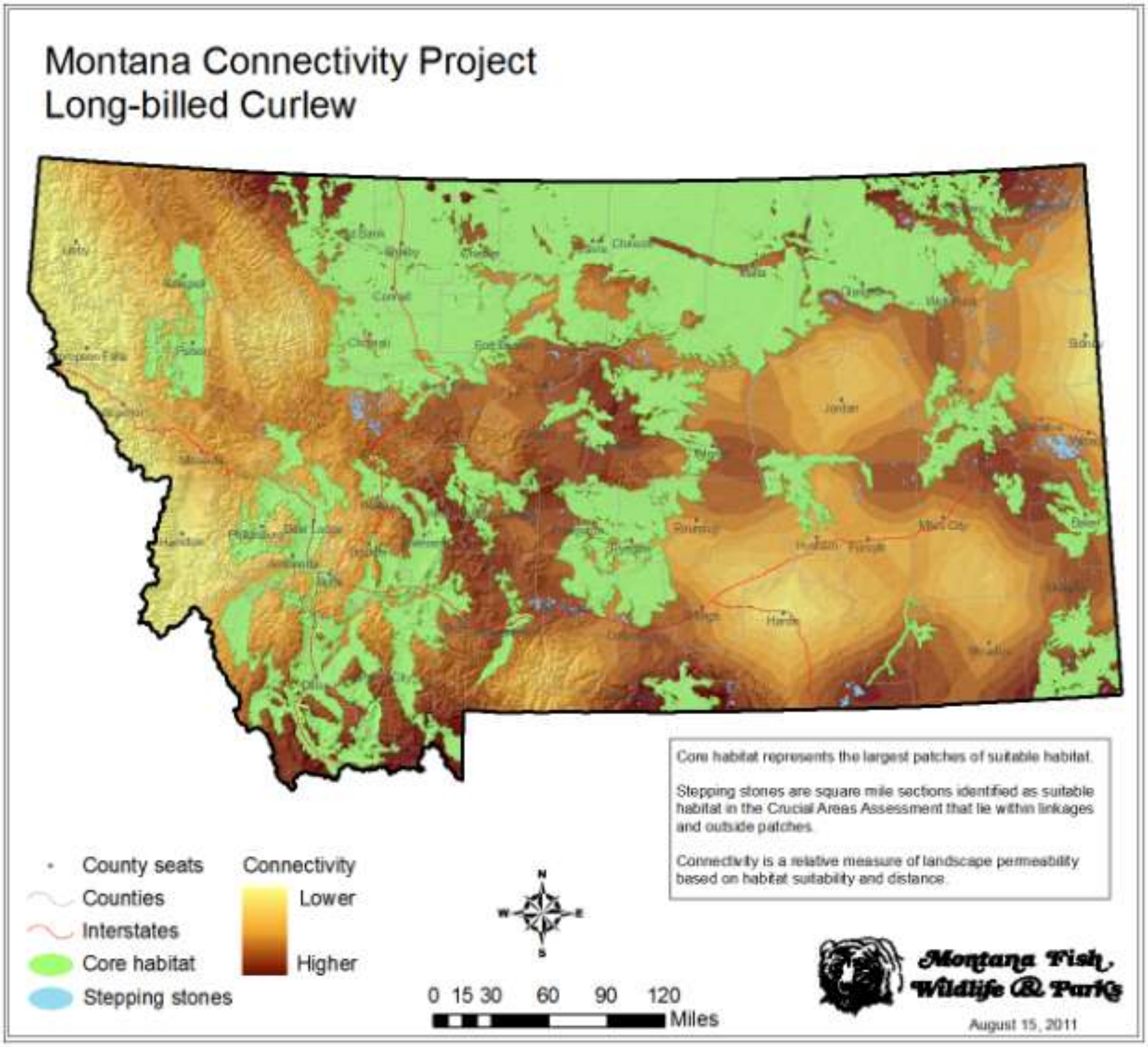


Figure 28. Long-billed Curlew core habitat, stepping stones, and potential range/statewide landscape connectivity.

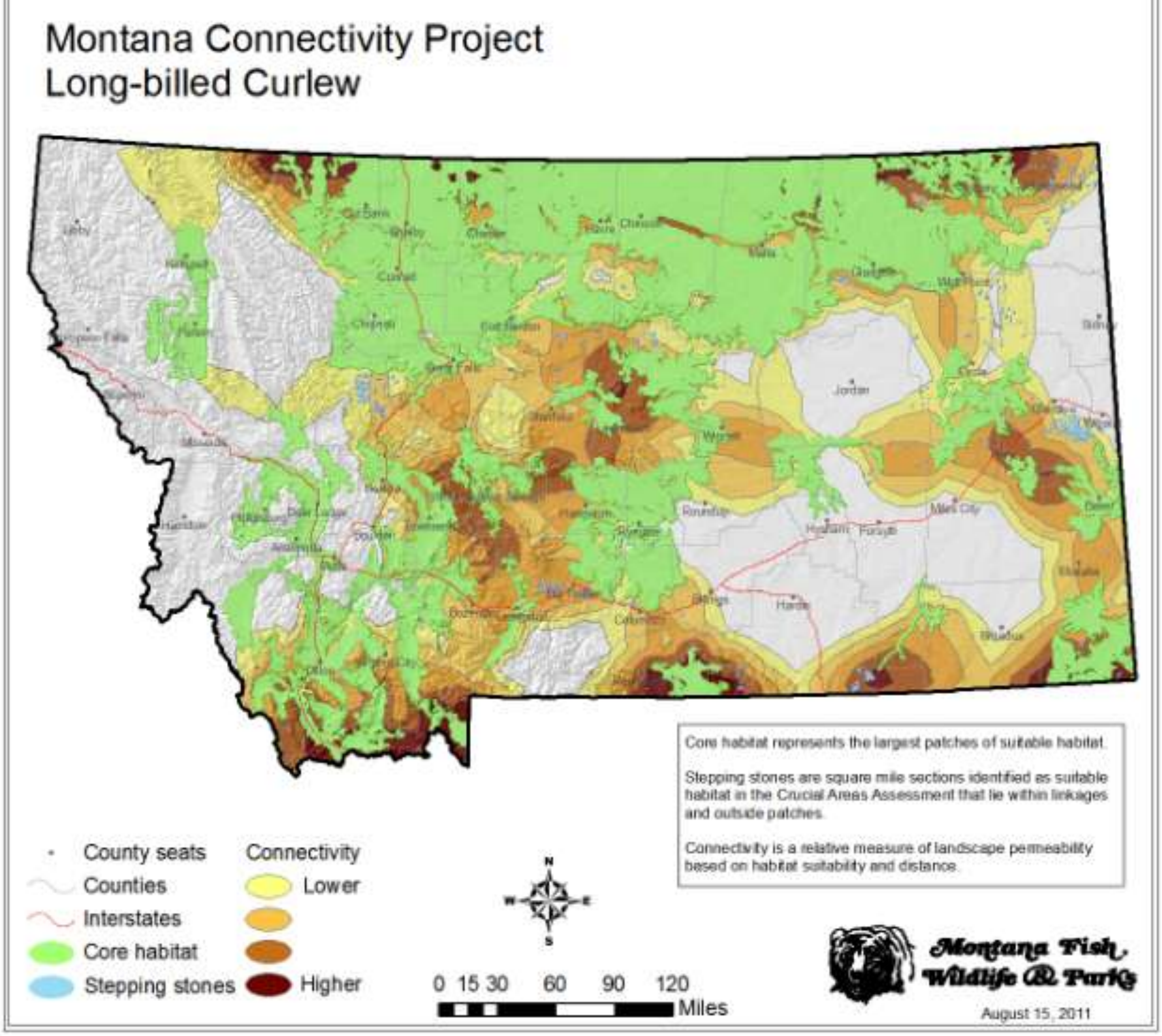


Figure 29. Long-billed Curlew Core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.9. Mountain Plover (Charadrius montanus)

Group: Avian

Ecosystem: Grassland/shrub

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G3/S2B

Confidence Rating: Core (Medium) Connectivity (Medium)

Figure 30. Mountain Plover Range

Introduction: Mountain plover is a seasonal migrant that breeds in Montana. It is rare east of the Continental Divide. Mountain plover is commonly associated with Grassland, Shrubland, Steppe, and Savanna, and Sparse and Barren systems. Habitat use in Montana appears similar to other areas within the breeding range; use of prairie dog colonies and other shortgrass prairie sites are confirmed as preferred breeding habitat.

Mountain plover was historically added to the state SOC list, but the date and proximate reasons are undocumented. Mountain plover was selected as a focal species to represent grassland environments, due to the fact that it is a SOC with 73% of Montana serving as breeding range. Mountain plover has been identified as an umbrella species for prairie dogs and longspurs (with mixed grass).

No management activities in Montana specific to mountain plover are regulated. Management practices should emulate these parameters and may include practices to: 1) identify, map, and protect areas where mountain plovers currently nest; 2) identify, map and protect prairie dog towns located on level shortgrass prairie habitats to ensure these populations persist; 3) areas of potential mountain plover habitat should not be converted to agriculture nor have range improvements that increase forage for livestock (particularly planting exotic grasses); 4) combine light to moderate grazing with prescribed burning, which has the added benefit of reducing woody species (Wershler 1989); 5) restrict off-road vehicle use between April 1 and August 1 in areas identified as potential mountain plover habitat; 6) maintain areas of intensive grazing on level (less than 10% gradient) shortgrass prairie communities; 7) efforts should be made to reduce the likelihood of invasion by non-native species such as (but not restricted to) cheatgrass, leafy spurge, and knapweed.

Section 1 – General Information
Supporting Information
- Undocumented

Patch Delineation
- Mountain plover patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having 2% or greater habitat suitability within a 58 hectare area were delineated. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).
- Habitat patches may have been adjusted based on feedback from species experts**.**

Connectivity Delineation
- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the % area calculation.

Assumptions:
- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by mountain plover.
  - The parameters listed in Section 3 for patch development generally represent mountain plover behavior.
  - The selected habitat patches include the largest and “best” areas supporting mountain plover.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
  - Given that little is understood about movement behavior, we are assuming that connectivity can be addressed by ensuring sufficient stop-over sites between summer and winter ranges.

- Assumptions associated with linkage delineation
    - Mountain Plover move into and out of the state along a generally north-south movement path.
    - Mountain Plover migration paths balance traveling the shortest distance with remaining over suitable habitat.
    - Mountain Plover can easily move within 5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment - Complete

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
    - Mountain plover locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than 400m. A total of 1001 locations were used for model training and 333 locations were used for model testing.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
    - AUC from test data = 0.990. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation – Complete

We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on mountain plover literature (Dechant et al 2002).
    - Model threshold (cutoff value between suitable and unsuitable habitat) = 2
    - Perceptual distance (how far away is suitable habitat perceived) = 300 meters
    - Population patch size (minimum area needed to support a population) = 58 hectares
- Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). Final patch layer has 40 patch polygons.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.

- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with “most likely” connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated between each of the border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow birds to migrate from the state boundaries to each patch region.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review and comments received (Appendix F).

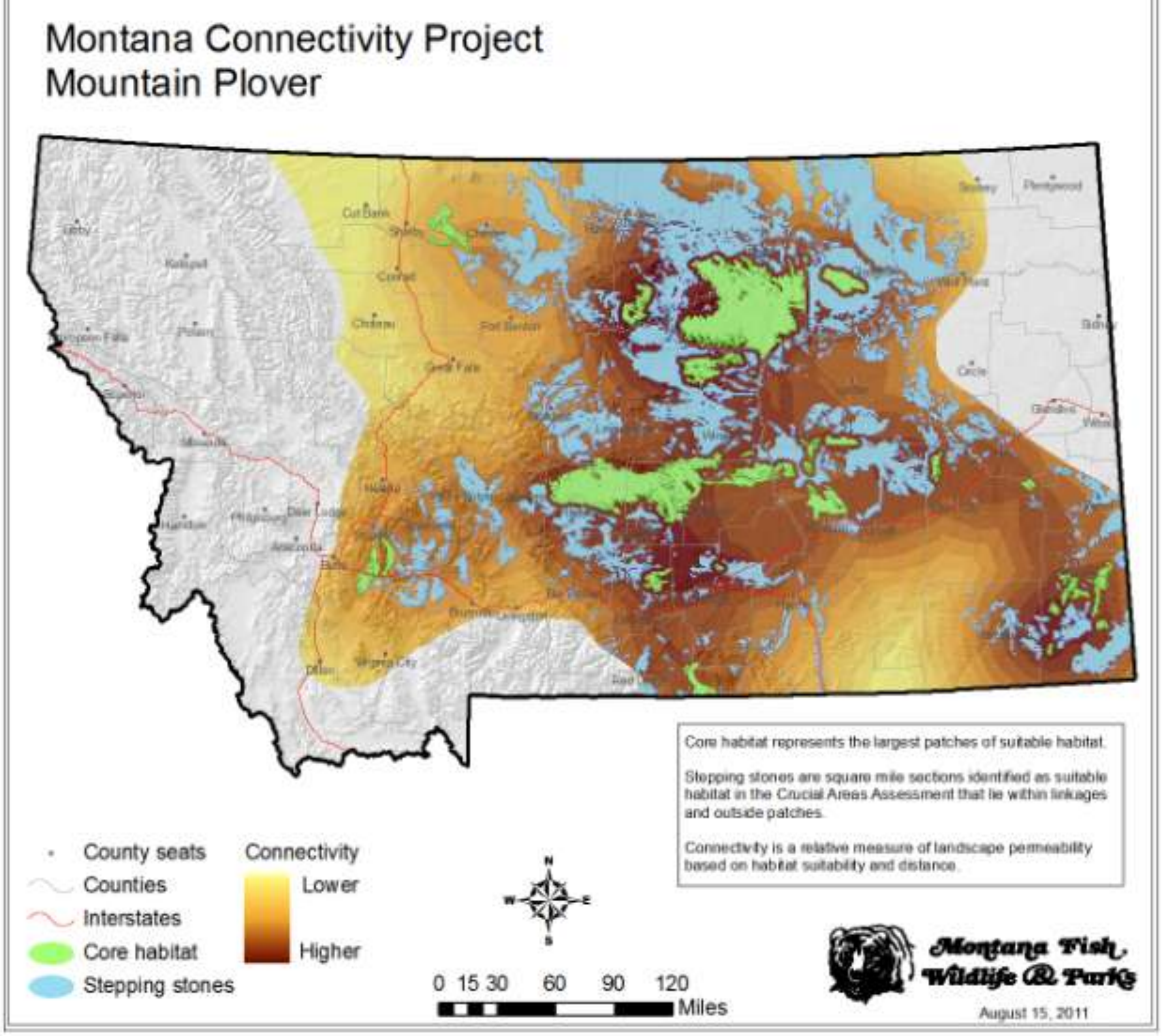


Figure 31. Mountain Plover core habitat, stepping stones, and potential range/statewide landscape connectivity.

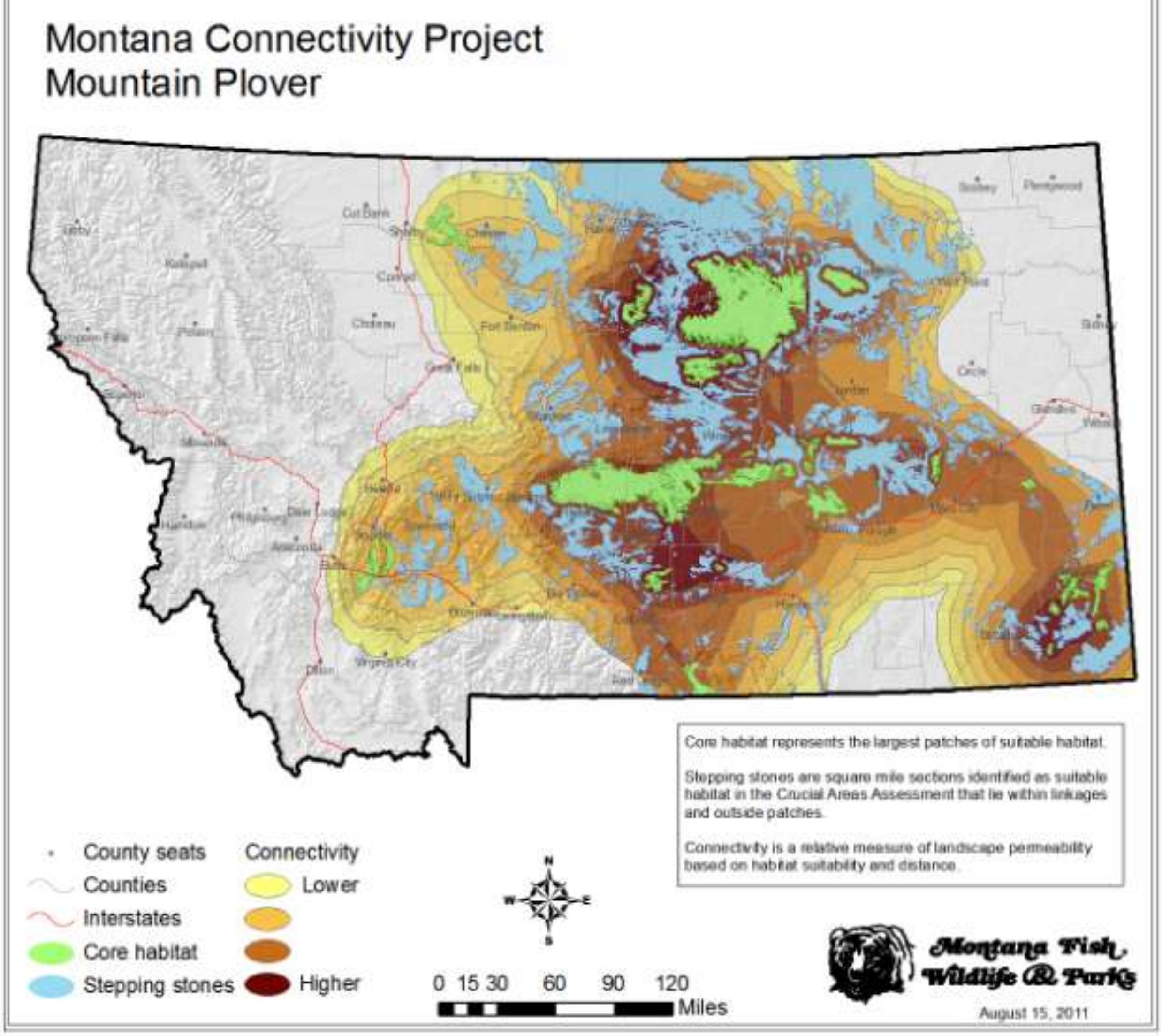


Figure 32. Mountain Plover core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.10. Northern Leopard Frog (Rana pipiens)

Group: Amphibian

Ecosystem: Riparian/Wetland

Type of connectivity: Within Season/Seasonal

Global/State Species of Concern Rank: G5/S1, S4

Confidence Rating: Core (Low) Connectivity (Low)

Figure 33. Northern Leopard Frog Range

Introduction: Northern leopard frog is a year-round resident of Montana. It is commonly associated with Open Water and Wetland and Riparian systems. Habitats used by Northern Leopard Frog in Montana are include low elevation and valley bottom ponds, spillway ponds, beaver ponds, stock reservoirs, lakes, creeks, pools in intermittent streams, warm water springs, potholes, and marshes (Brunson and Demaree 1951, Mosimann and Rabb 1952, Black 1969, Miller 1978, Dood 1980, Reichel 1995, Hendricks and Reichel 1996, Hendricks 1999).

Northern leopard frog was added to the state SOC list in 1996 due to catastrophic population declines in western Montana and apparent declines in eastern Montana. In eastern Montana Northern leopard frog was downgraded in 2009 due to widespread occupancy of suitable habitat. Western Montana populations, which have been nearly extirpated since the early 1980s, remain at an S1 level of risk. Northern leopard frog is a seasonal migrant and natal disperser. It was selected as a focal species to represent wetland environments, due to the fact that it is a SOC with 72% of Montana serving as breeding range. Northern leopard frog has been identified as an umbrella species for great plains toad, black tern, and northern pintail.

No special management needs are currently recognized for populations in eastern Montana. However, at permanent and semi-permanent water bodies (reservoirs and stock ponds) where breeding has been observed, portions of shorelines where emergent vegetation is present or might develop could be fenced to exclude access by livestock and thereby protect breeding adults, eggs and tadpoles from trampling and the removal of emergent cover by livestock.

Section 1 – General Information
Supporting Information

- Northern leopard frog locations obtained from Montana Natural Heritage Program.

Patch Delineation

- Northern leopard frog patches delineated for this project represent areas likely to support the species across seasons by providing multiple wetlands with access to riparian areas for long distance movements**.**
- Patches were obtained by identifying 1 sq mile sections that have wetland complexes and giving more weight to complexes near streams. (See section 2 and section 3 for more information on habitat assessment and patch delineation).

Connectivity Delineation

- Because Northern leopard frog seasonal movements are small, connectivity will be addressed by identifying those 1-sq mile sections predicted to have suitable habitat conditions in the patch delineation step.

Assumptions:

- Sections with multiple wetlands that are near streams are more likely to provide suitable habitat for Northern Leopard Frog.

Section 2 – Habitat Quality Assessment

Northern Leopard Frogs breed in permanent or ephemeral waters with emergent vegetation and forage in aquatic margins and terrestrial habitats (Hendricks 1999, Maxell 2000, Maxell et al. 2003). They overwinter in deep water bodies and streams and often move between seasonal habitats (Hendricks 1999, , Maxell 2000, Maxell et al. 2003). Leopard frogs move 300 to 400 meters between seasonal habitats and can disperse long distances along riparian areas (Maxell, pers comm) .

- Habitat quality for Northern Leopard Frog is based on seasonal habitat needs, dispersal habitat needs and known movement distances.
- Input Layers
    - Wetlands layer developed for the Crucial Areas Assessment.
    - National Hydrography Dataset - flowlines.
- Analysis
    - Identify wetlands that are within 300 meters of a stream.

Section 3 – Habitat Patch Delineation

Habitat patches are based on the spatial arrangements of wetlands and streams within a section.

- The number of wetlands in a section that are within 300 meters of each other was calculated.
- The number of wetlands within 5 meters of a stream was also calculated.
- Sections were then given a total score based on the above calculations.
- Sections with a score of 10 or higher were highlighted.

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 1 multi-part patch.

Section 4 – Connectivity Analysis

Because Northern leopard frog seasonal movements are small relative to the resolution of the final connectivity project, connectivity will be addressed by applying management recommendations to sections predicted to have suitable occupancy and connectivity habitat.

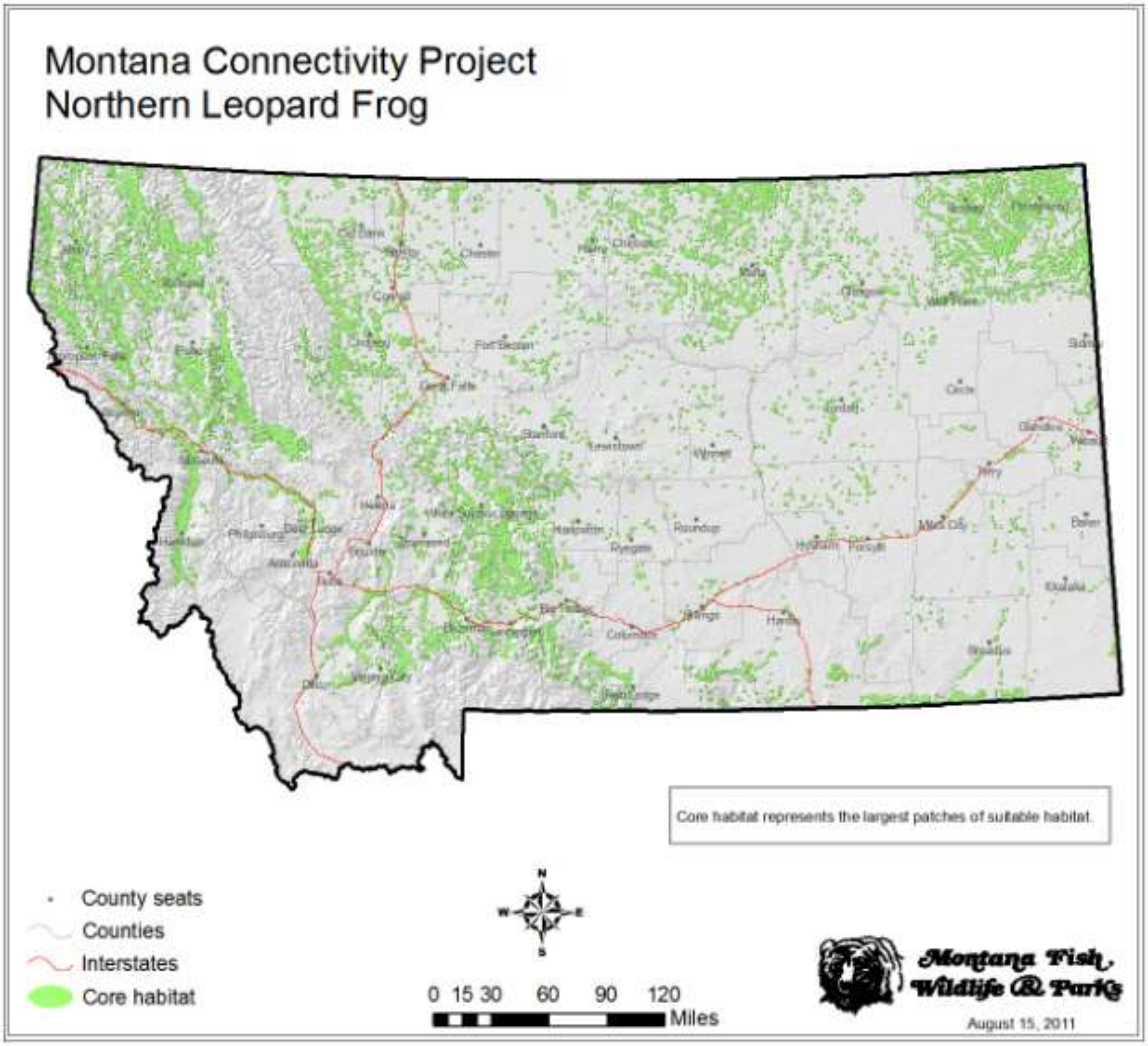


Figure 34. Northern Leopard Frog core habitat and potential range/statewide landscape connectivity.

3.1.11. Piping Plover (Charadrius melodus)

Group: Avian

Ecosystem: Riparian/Wetland

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G3/S2B, Threatened

Confidence Rating: Core (Low) Connectivity (NE)

Figure 35. Piping Plover Range

Introduction: Piping plover is a seasonal migrant that breeds in Montana. It is commonly associated with Open Water and Wetland and Riparian systems. Piping Plovers primarily select unvegetated sand or pebble beaches on shorelines or islands in freshwater and saline wetlands. Vegetation, if present at all, consists of sparse, scattered clumps (Casey 2000). Open shorelines and sandbars of rivers and large reservoirs in the eastern and north-central portions of the state provide prime breeding habitat (MFWP 2003). Nesting may occur on a variety of habitat types.

Piping plover was historically added to the state SOC list, but the date and proximate reasons are undocumented. Piping plover was selected as a focal species to represent prairie lake and river shoreline environments, due to the fact that it is a SOC with 11% of Montana serving as breeding range. Piping plover has not been identified as an umbrella species.

Four specific geographic areas, recognized as providing critically important habitat and identified as essential for the conservation of the species, have been designated as "Critical Habitat Units" in Montana. The designation of critical habitat may require federal agencies to develop special management actions affecting these sites. The four units include prairie alkali wetlands and surrounding shoreline; river channels and associated sandbars and islands; and reservoirs and inland lakes with associated shorelines, peninsulas, and islands (USFWS 2003).

Section 1 – General Information
Supporting Information

- Piping plover locations (See section 2 for more information on piping plover locations).

Patch Delineation

- Piping plover patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix interspersed with small areas of suitable habitat.

- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches having an average value greater than a given suitability threshold within a 1 hectare area were delineated (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).
- Habitat patches may have been adjusted based on feedback from species experts**.**

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- A cost surface was generated by multiplying the habitat suitability model by 0.5 in mountainous areas and inverting the resulting values..
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the percent area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by Piping plover.
  - The parameters listed in Section 3 for patch development generally represent Piping plover behavior.
  - The selected habitat patches include the largest and “best” areas supporting Piping plover breeding pairs.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
  - Piping plovers move into and out of the state along a generally north-south movement path.
  - Flying over high mountain ridges imposes a potential cost (particularly during inclement weather) and piping plovers will preferentially avoid ridgelines given a choice.
  - Piping plover migration paths balance traveling the shortest distance with remaining over suitable habitat.
  - Piping plovers can easily move within 5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment
Piping plover utilize wide, sparsely vegetated sand or gravel beaches on shorelines or islands in freshwater wetlands (USFWS 2003). Males establish territories along shorelines but these change seasonally and often overlap with other breeding pairs. Territories have been observed to range from 4000 square meters to 30,547 hectares (Haig 1992.)

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
  - Piping plover locations
    - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with breeding behavior and with a spatial uncertainty smaller than 400m. A total of 288 locations were used for model training and 95 locations were used for model testing.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
  - AUC from test data = 0.996. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation
We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on Piping plover information (Haig 1992, USFS 2010).
  - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 3
  - Perceptual distance (how far away is suitable habitat perceived) = 180 meters
  - Breeding patch size (minimum area needed to support a breeding pair) = 1 hectare. Based on smallest territory size observed for this species and the resolution of the data.
- Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.

- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with “most likely” connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated between each of the border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow birds to migrate from the state boundaries to each patch region.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review and comments received (Appendix F).

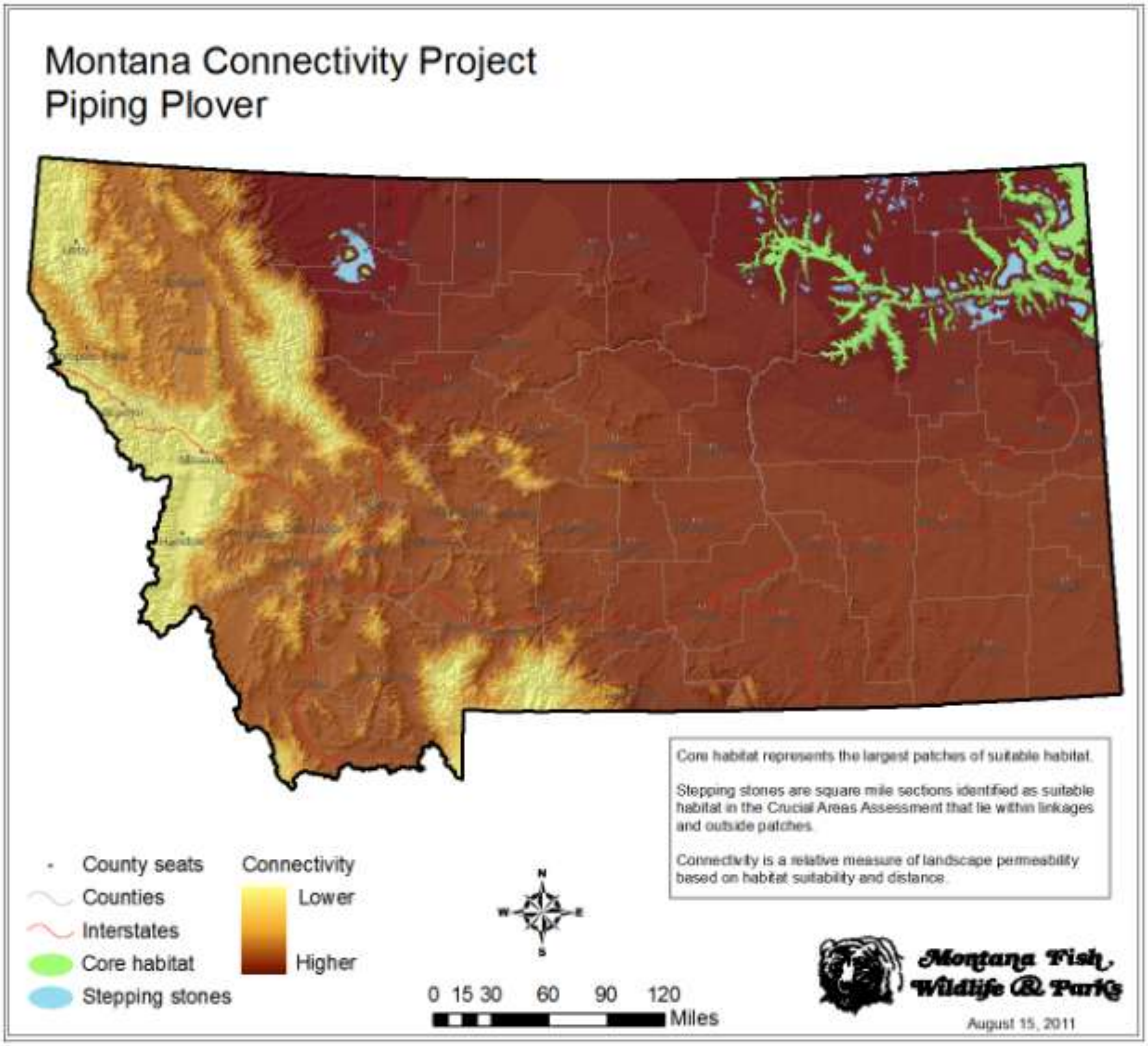


Figure 36. Piping Plover core habitat, stepping stones, and potential range/statewide landscape connectivity.

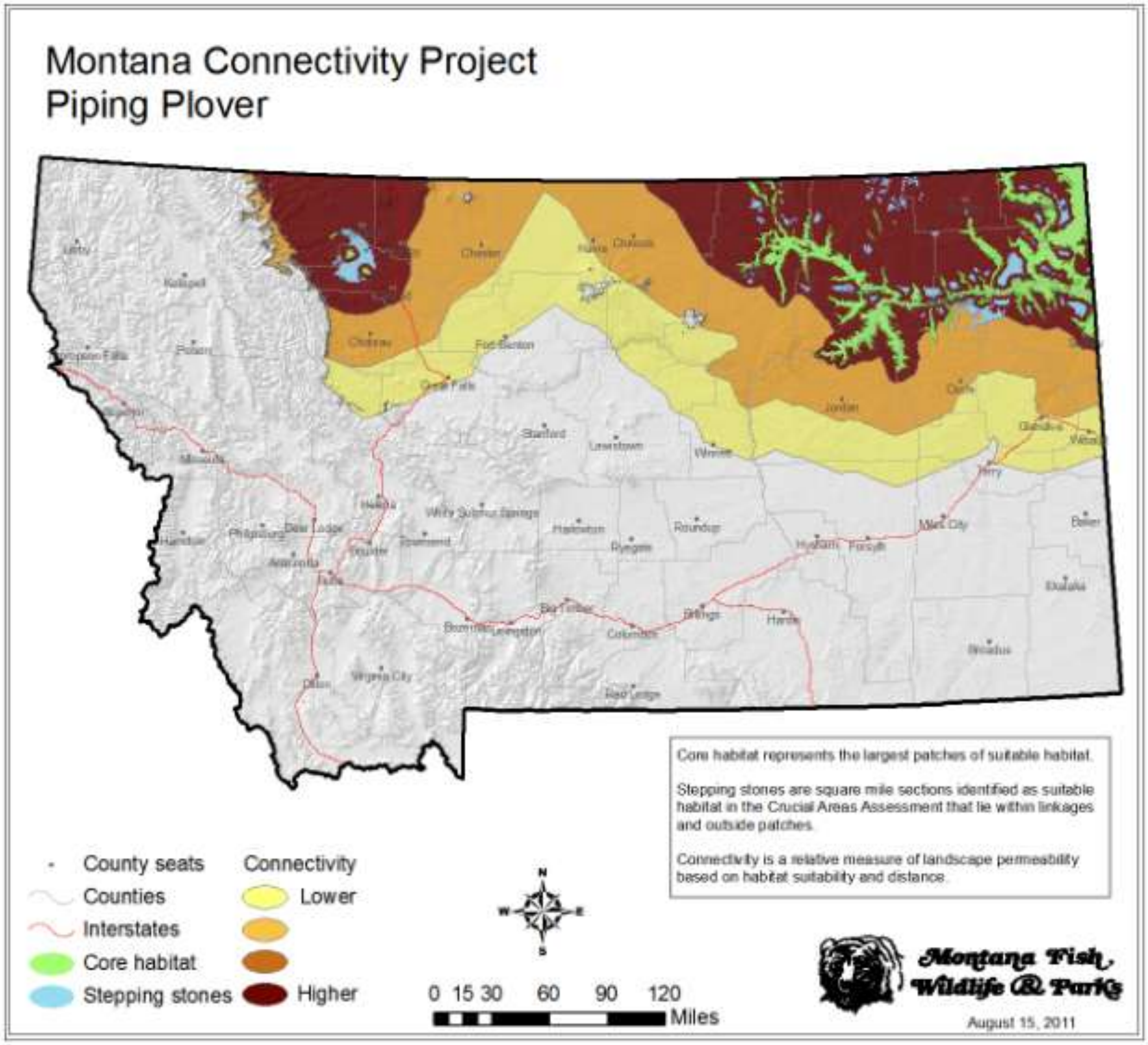


Figure37. Piping Plover core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.

3.1.12. Pygmy Rabbit (Brachylaagus idahoensis)

Group: Mammal

Ecosystem: Shrub-steppe

Type of connectivity: Long-term, Range Expansion/Shift

Global/Montana SOC Rank: G4/S3

Confidence Rating: Core (Medium) Connectivity (Medium)

Figure 38. Pygmy Rabbit Range

Introduction: Pygmy rabbit is a resident of Montana. It is commonly associated with Shrubland, Steppe, and Savanna systems. Occupied habitats in Montana include shrub-grasslands on alluvial fans, floodplains, plateaus, high mountain valleys, and mountain slopes, where suitable sagebrush cover and soils for burrowing are available. Some occupied sites may support a relatively sparse cover of sagebrush and shallow soils, but these usually support patches of dense sagebrush and deeper soils. Big sagebrush was the dominant shrub at all occupied sites.

Pygmy rabbit was added to the state SOC list in 1992 for undocumented reasons. Pygmy rabbit was selected as a focal species to represent sagebrush environments. Pygmy rabbit serves as an umbrella species for sage grouse, sage thrasher, sage sparrow, Brewer's sparrow, and sharp-tailed grouse.

No special management activities have been developed or implemented in Montana specifically for pygmy rabbits. The loss of habitat from conversion to cropland and pasture is probably not great in southwestern Montana. Burning and other methods of sagebrush removal, however, have been used in past and recent years to improve rangeland for livestock. Such activity will make the landscape unsuitable for pygmy rabbits.

Section 1 – General Information
Supporting Information –

- Pygmy rabbit locations (see Section 2 for more information on location data).

Patch Delineation

- Pygmy rabbit patches delineated for this project represent the 20 largest areas of suitable habitat separated by a less suitable matrix interspersed with smaller areas of suitable habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive). The model output was smoothed to remove isolated grids and patches

having an average value greater than a given suitability threshold within a 1hectare area were delineated.   Agricultural areas were clipped from the final habitat patches. (See section 2 for more details on habitat suitability models and section 3 for more information on patch delineation).

- Habitat patches may have been adjusted based on feedback from species experts**.**

Connectivity Delineation

- Linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Corridor values were calculated for all pair-wise patch combinations and combined to produce a composite least-cost surface for the entire analysis area.

Assumptions:

- Assumptions associated with habitat and patch delineation
    - The habitat suitability model adequately represents landscape conditions preferred by Pygmy rabbit.
    - The parameters listed in Section 3 for patch development generally represent Pygmy rabbit behavior.
    - The selected habitat patches include the largest and “best” areas supporting Pygmy rabbit.
- Assumptions associated with linkage delineation
    - Pygmy rabbits are relatively constrained to suitable habitat and preferentially move within suitable habitat when dispersing.
    - No assumptions regarding dispersal distances within which “perfect” connectivity can be assumed were implied. All habitat patches were analyzed as discrete patches for connectivity analysis.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
    - Pygmy rabbit locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with a spatial uncertainty smaller than 400m. A total of 553 locations were used for model training and 184 locations were used for model testing.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance

- AUC from test data = 0.943. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation
We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Literature reviews of Pygmy rabbit behavior (Katzner and Parker 1997, Rauscher 1997) shows that the average home range (2,568 m^2) is smaller than the resolution of the underlying habitat model (8100 m^2). Therefore, parameters were chosen that are small but still include some variability in the data.
  - Model threshold (cutoff value between suitable and unsuitable habitat) = 9
  - Perceptual distance (how far away is suitable habitat perceived) = 134 meters
  - Population patch size (minimum area needed for a population) = 1 hectare
- The habit patches obtained from the patch tool were further adjusted by using recent information to remove agricultural areas.

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 4 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.
- Corridor rasters were generated between core habitat patches. All possible pair-wise combinations were calculated.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Linkage maps were submitted for review and comments received (Appendix F).

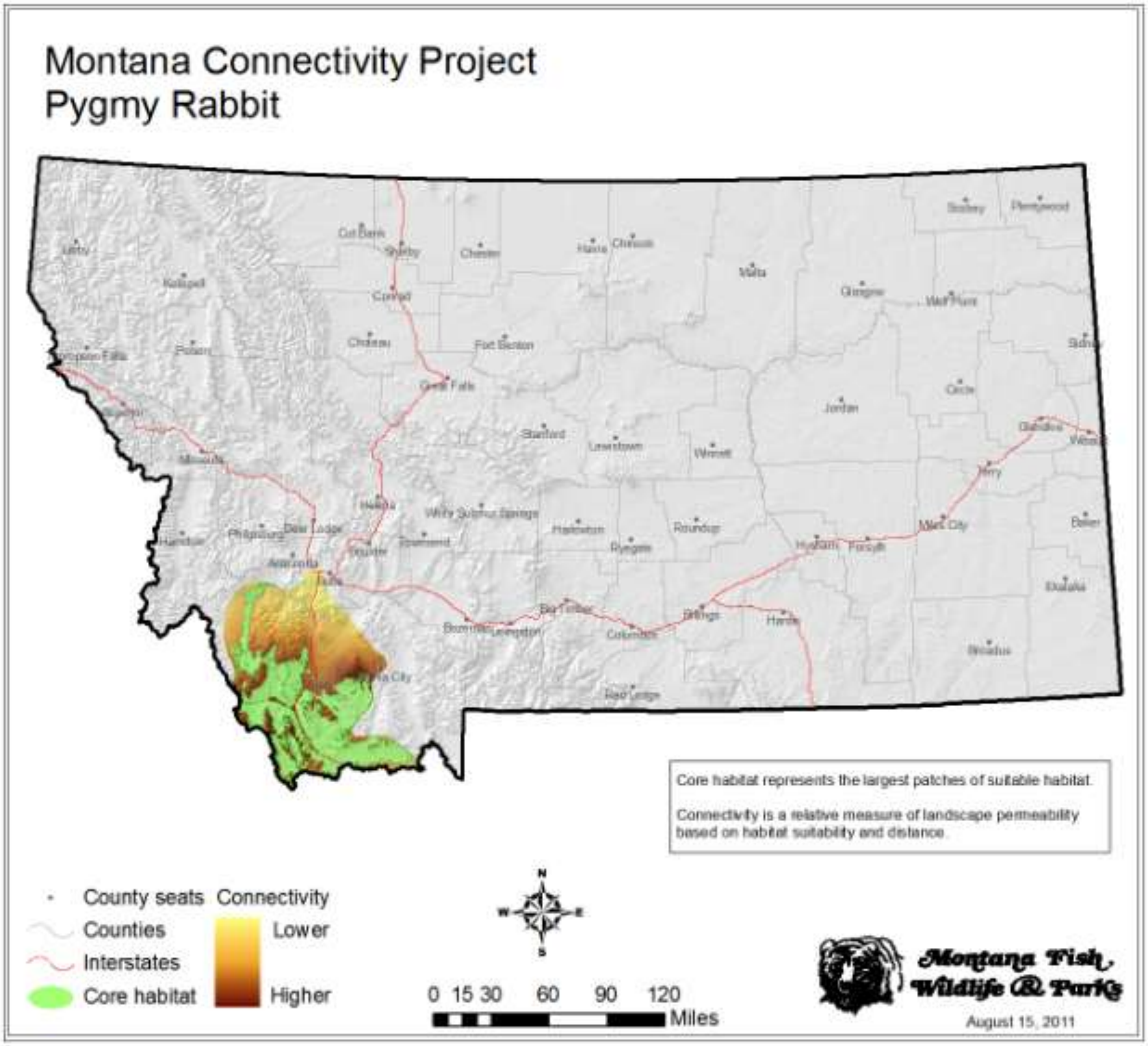


Figure 39. Pygmy Rabbit core habitat and potential range/statewide landscape connectivity.

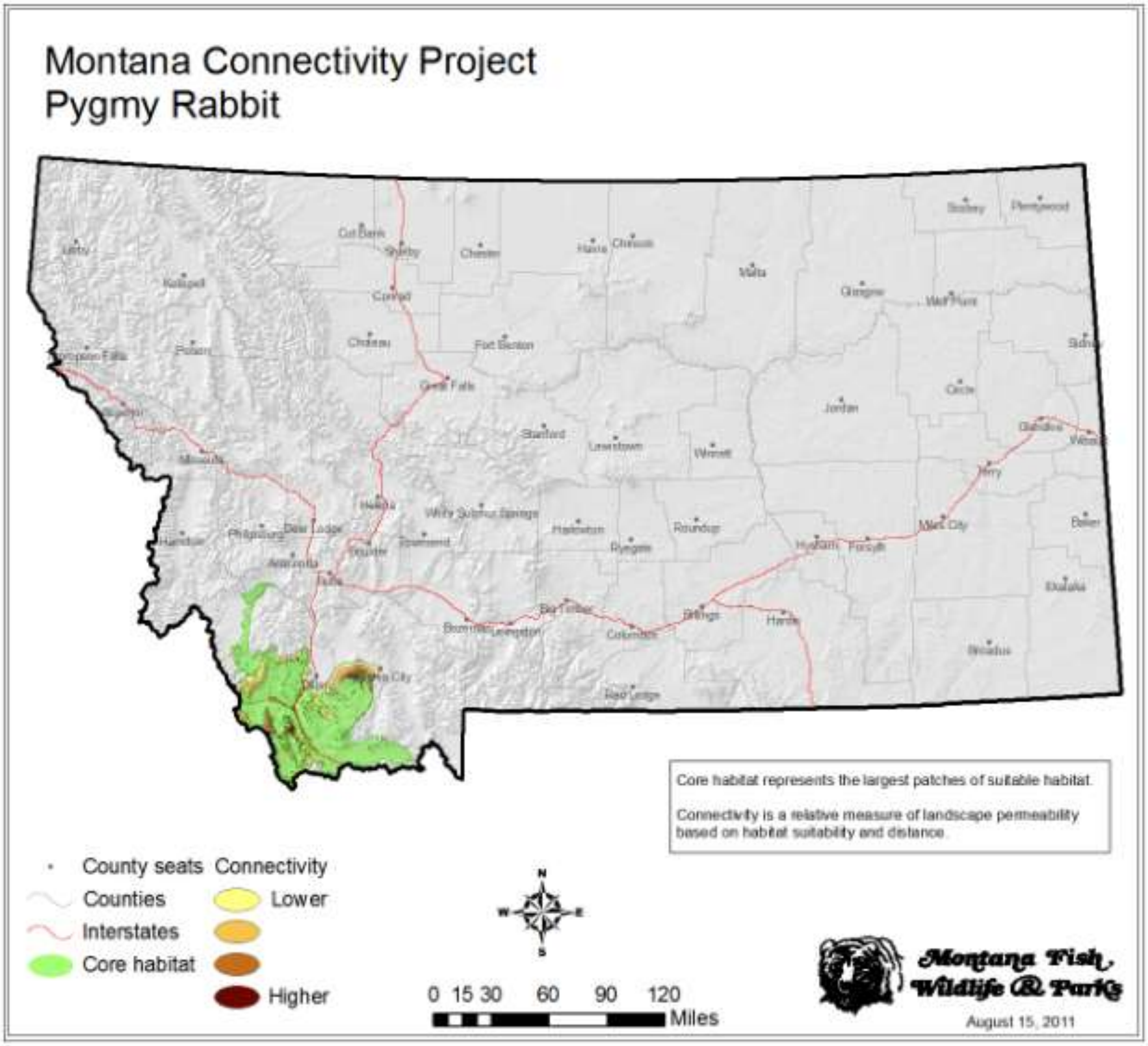


Figure 40. Pygmy Rabbit core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.13. Rufous Hummingbird (Selasphorus rufus)

Group: Avian

Ecosystem: Riparian/Wetland

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G5/S4B

Confidence Rating: Core (Low) Connectivity (NE)

Figure 41. Rufous Hummingbird Range

Introduction: Rufous hummingbird is a seasonal migrant that breeds in Montana. It is commonly associated with Forest and Woodland, Grassland, Shrubland, Steppe, and Savanna, and Wetland and Riparian systems. Rufous hummingbirds generally occupy cool environments, principally secondary succession communities and openings, forested and brushy habitats of the northern Rocky Mountains. It typically nests in second growth and mature forests (Calder 1993).

Rufous hummingbird was historically added to the state SOC list, but the date and proximate reasons are undocumented. Rufous hummingbird was selected as a focal species to represent woody wetland and riparian environments, due to the fact that it is a SOC with 45% of Montana serving as breeding range. Rufous hummingbird has been identified as an umbrella species for black swift, Lewis' woodpecker, veery and ovenbird.

No management activities specific to rufous hummingbird are currently occurring in Montana.

Section 1 – General Information

Supporting Information

- Rufous hummingbird locations (see Section 2 for more information on location data).

Patch Delineation

- Rufous hummingbird patches delineated for this project represent the 20 largest areas of potential habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive) and reduced to the extent of the range of the species (as identified by the MNHP).
- Habitat patches may have been adjusted based on feedback from species experts.

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by Rufous hummingbird.
  - The parameters listed in Section 3 for patch development generally represent Rufous hummingbird behavior.
  - The selected habitat patches include the largest and "best" areas supporting Rufous hummingbird.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
  - Rufous hummingbirds move into and out of the state along a generally north-south movement path.
  - Rufous hummingbird migration paths balance traveling the shortest distance with remaining over suitable habitat.
  - Rufous hummingbirds can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
  - Rufous hummingbird locations
    - Three-hundred and thiry six point observations were used as inputs to this model (25% withheld for testing). Five replicate runs were performed.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species. The following layers were used in this model: Soil Temp, Average Minimum Temperature, STATSGO Soil Units, Ecoregions, Soils, Maximum Annual Temperature, Elevation, NLCD Landcover, Average Precipitation, Slope, Distance to Stream, North-South Aspect, East-West Aspect, Solar Radiation Index (Summer Solstice), Solar Radiation Index (Winter Solstice), Solar Radiation Index (Equinox), and Ruggedness
- Habitat suitability model performance

The average test AUC for the replicate runs is 0.941, and the standard deviation is 0.008.

Section 3 – Habitat Patch Delineation

We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on a brief review of documents available on-line via Google searches.
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 19 (using rescaled Maxent model -- value was actually 19.4, this was rounded down as the model only accepts integers)
    - Perceptual distance (how far away is suitable habitat perceived) = 2000 meters (Calder 1993 notes individuals found at feeders 2 km apart) -- (Also found information suggesting 40243 meters (this is a representation of daily distance flown during migration))
    - Breeding patch size (minimum area needed to support breeding) = 0.33 ha (Feeding territory sizes range from 32 to 3,300 square meters (Gass 1979; Kodric-Brown and Brown 1978, see below NatureServe URL below)
    - Population patch size (minimum area needed to support a population) = 1.65 ha (as per suggestion in the CorridorDesigner patch tool).
    - The 20 largest patches were used to represent the major areas supporting RUHUs.

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with “most likely” connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated between the north and south border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow the species to move across state boundaries to at least one (and quite often more) patch region(s).
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Linkage maps were submitted for review and comments received (Appendix F).

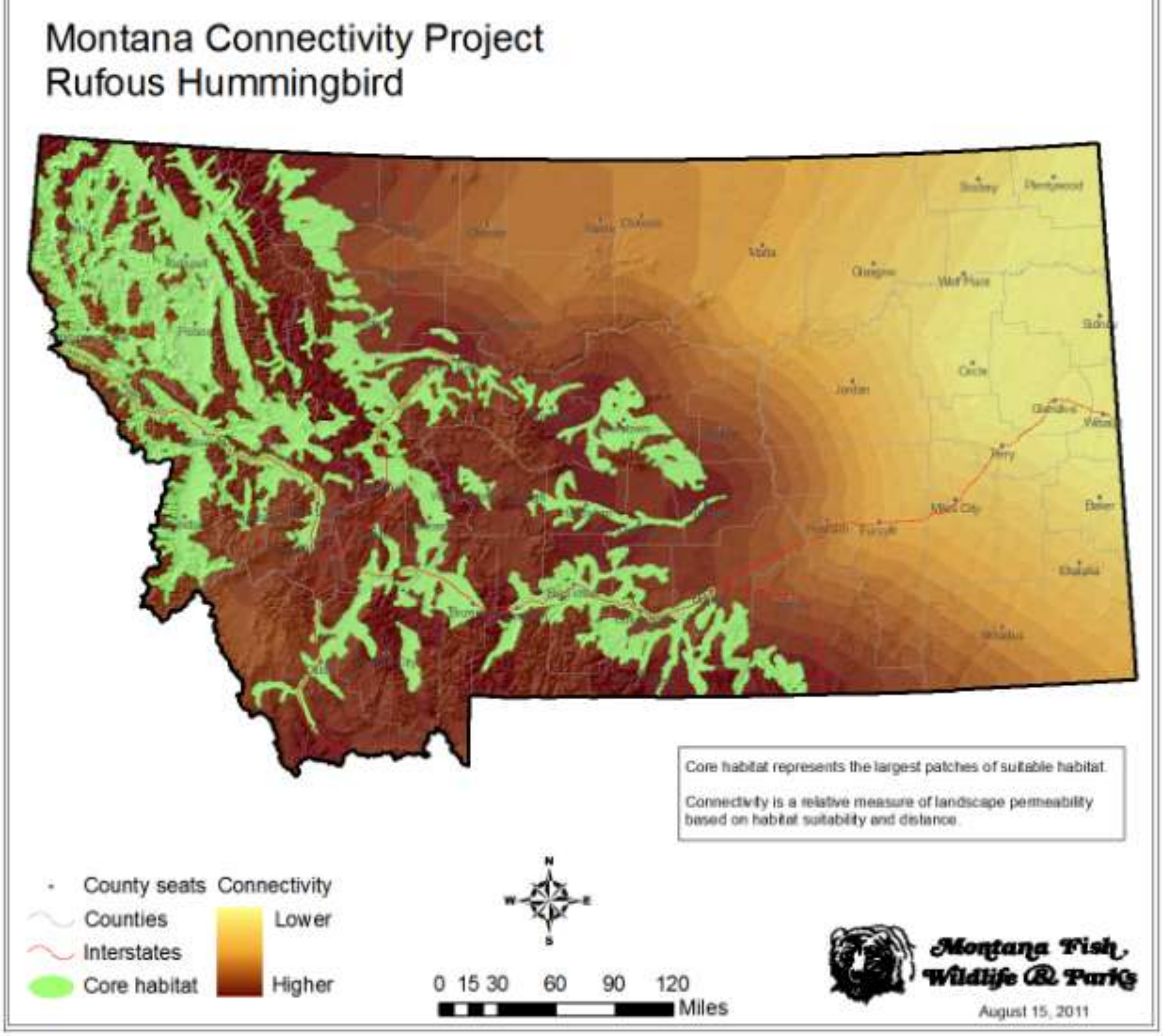


Figure 42. Rufous Hummingbird core habitat and potential range/statewide landscape connectivity.

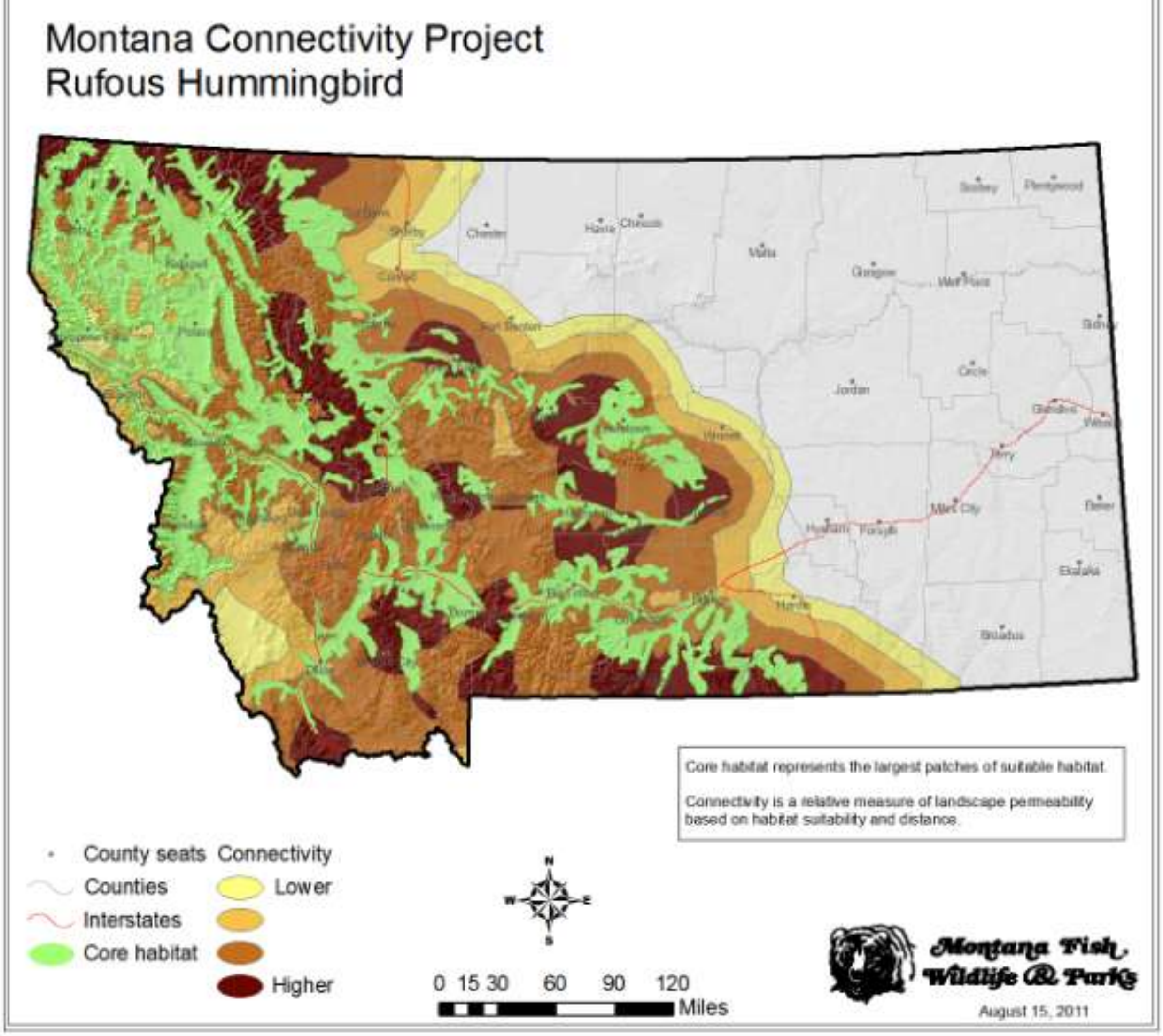


Figure 43. Rufous Hummingbird core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.14. Swift Fox (Vulpes velox)

Group: Mammal

Ecosystem: Grassland/Shrub

Type of connectivity: Within season/long-term

Global/State Species of Concern Rank: G3/S3

Confidence Rating: Core (Medium) Connectivity (Low)

Figure 44. Swift Fox Range

Introduction: Swift fox is a year-round resident of Montana and are not migratory. It is commonly associated with Grassland systems and occasionally associated with Wetland and Riparian, Shrubland, Steppe, and Savanna, and Sparse and Barren systems. Swift Fox inhabit open prairie and arid plains, including areas intermixed with winter wheat fields in north-central Montana. They use burrows when they are inactive; either dug by themselves or made by other mammals (marmot, prairie dog, badger). Populations from Canada continue to expand to the south and east in Montana. Recent surveys in Montana have documented swift fox in many of the counties bordering Canada in north-central Montana (Moehrenschlager and Moehrenschlager 2001).

Swift fox was historically added to the state SOC list, but the date and proximate reasons are undocumented. Swift fox were thought to be common on the eastern plains of Montana in the early 1900's but were exterminated and believed to be extinct in the state by 1969 (Hoffmann et al. 1969). It was selected as a focal species to represent grassland environments, due to the fact that it is a SOC with 69% of Montana serving as breeding range. Swift fox has been identified as an umbrella species for pronghorn, mule deer, black-tailed prairie dog, and Townsend's big-eared bat.

Section 1 – General Information
Supporting Information

- Swift fox locations (see Section 2 for more information on location data).

Patch Delineation

- Swift fox patches delineated for this project represent the 20 largest areas of potential habitat.
- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive) and reduced to the extent of the range of the species (as identified by the MNHP).
- Patches were derived using the original model as per reviewer feedback (Ryan Rauchor).
- Patches were also created using a model from the World Wildlife Fund.

- Both sets of patches will be available for review.
- Habitat patches may have been adjusted based on feedback from species experts**.**

Connectivity Delineation

- Linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- A cost surface was generated by inversing the values in the habitat suitability model described above.
- Corridor values were calculated for all pair-wise patch combinations and combined to produce a composite least-cost surface for the entire analysis area.

Assumptions:

- Assumptions associated with habitat and patch delineation
    - The habitat suitability model adequately represents landscape conditions preferred by swift fox.
    - The parameters listed in Section 3 for patch development generally represent swift fox behavior -- specifically that associated with females.
    - The selected habitat patches include the largest and "best" areas supporting swift fox.
- Assumptions associated with linkage delineation
    - Swift foxes are relatively constrained to suitable habitat and preferentially move within suitable habitat when dispersing.
    - No assumptions regarding dispersal distances within which "perfect" connectivity can be assumed were implied. All habitat patches were analyzed as discrete patches for connectivity analysis.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
    - Swift Fox locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those associated with a spatial uncertainty smaller than 400m. A total of 328 locations were used for model training and 127 locations were used for model testing.
- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance

    - AUC from test data = 0.778 and standard deviation is 0.025. AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation

We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on a brief review of documents available on-line via Google searches.
    - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 59 (using rescaled Maxent model -- value was actually 58.9, this was rounded down as the model only accepts integers)
    - Reran the model using a threshold value of 100 (representing a threshold value of approx. 10%, given input values were rescaled to a 0-1000).
    - Dispersal distance average = 5500 meter radius (11000 meters diameter, Montana Field Guide - maximum was 64 k: see also David Ausband and Axel Moehrenschlager, Long-range juvenile dispersal and its implication for conservation of reintroduced swift fox Vulpes velox populations in the USA and Canada, 2009 Fauna & Flora International, Oryx, 43(1), 73–77: Nicholson, KL, WB Ballard, BK McGee, and HA Whitlaw, 2007, Dispersal and extraterritorial movements of swift foxes (Vulpes velox) in northwestern Texas, Western North American Naturalist, 67(1), 102-108.)
    - Breeding patch size (minimum area needed to support breeding) -- Used home range size = 880 ha (based on 20% of the average home range size according to SPECIES ASSESSMENT FOR SWIFT FOX (*VULPES VELOX*) IN WYOMING prepared by DARBY N. DARK-SMILEY AND DOUGLAS A. KEINATH for the BLM December 2003, Montana Field Guide suggested several square km)
    - Population patch size (minimum area needed to support a population) = 4400 ha (as per suggestion in the CorridorDesigner patch tool).
    - The 20 largest patches were used to represent the major areas supporting swift fox.
- Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.

- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

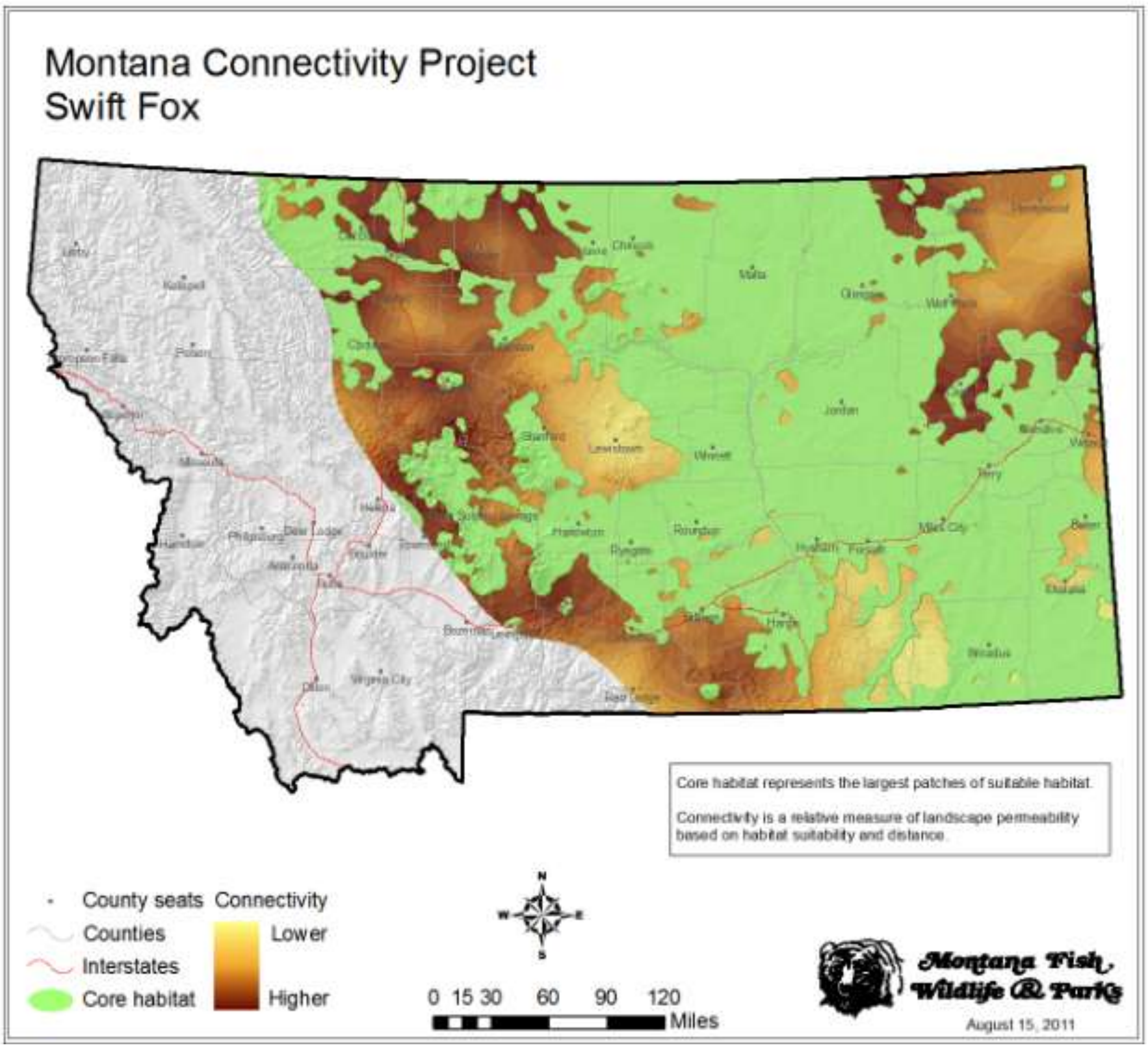


Figure 45. Swift Fox core habitat and potential range/statewide landscape connectivity.

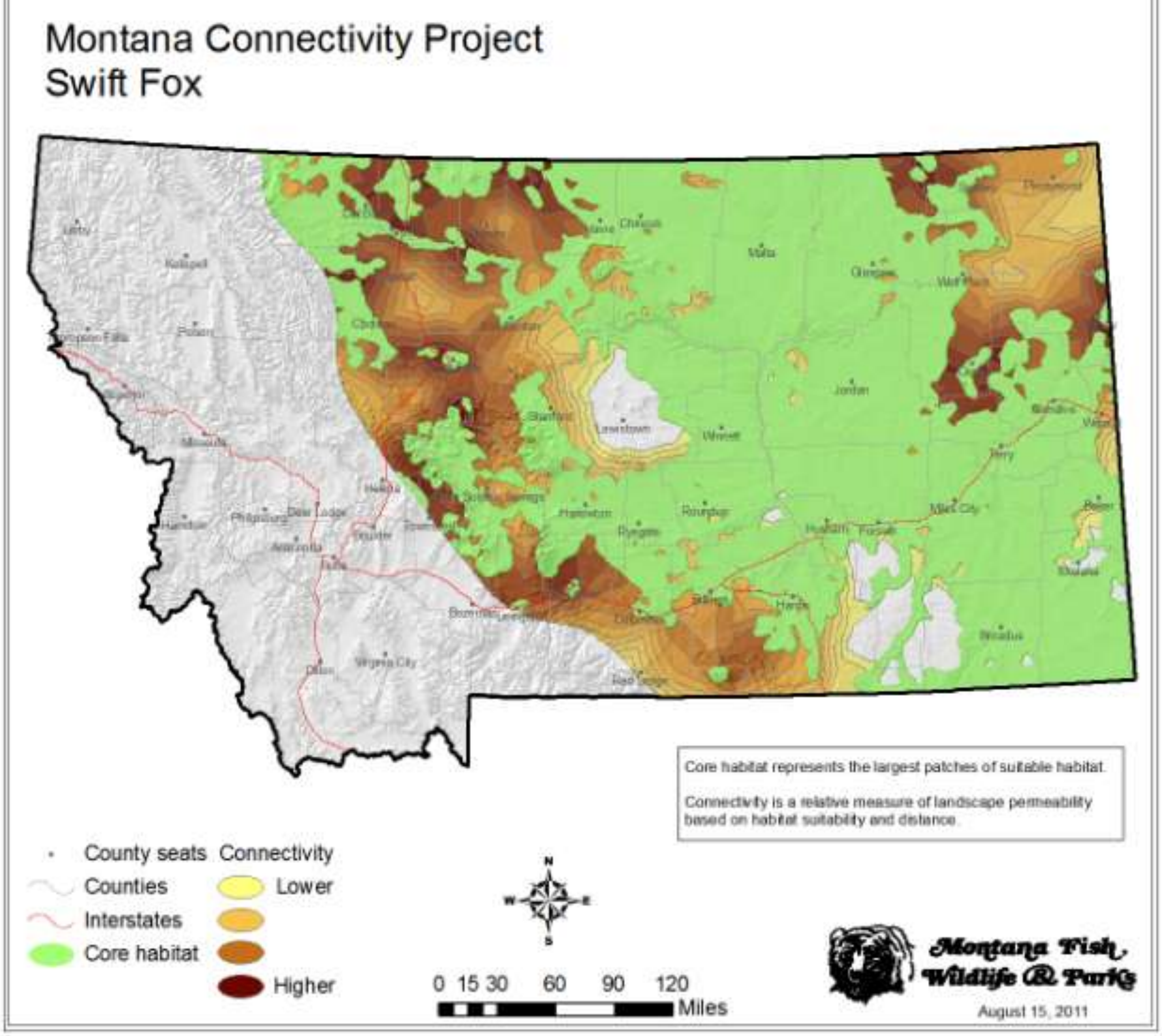


Figure 46. Swift Fox core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.15. Townsend's Big-eared Bat (Corynorhinus townsendii)

Group: Mammal

Ecosystem: Riparian/Wetland

Type of connectivity: Daily, Within season, seasonal

Global/State Species of Concern Rank: G4/S2

Confidence Rating: Core (Low) Connectivity (NE)

Figure 47. Townsend's Big-ear Bat

Introduction: Townsend's big-eared bat is a year-round resident of Montana. It is commonly associated with Forest and Woodland, Grassland, Shrubland, Steppe, and Savanna, Grassland, Wetland and Riparian, and Sparse and Barren systems. Habitat use in Montana has not been evaluated in detail, but seems to be similar to other localities in the western United States. Caves and abandoned mines are used for maternity roosts and hibernacula (Worthington 1991, Hendricks et al. 1996, Hendricks 2000, Hendricks et al. 2000, Foresman 2001, Hendricks and Kampwerth 2001); use of buildings in late summer has also been reported (Swenson and Shanks 1979). Habitats in the vicinity of roosts include Douglas-fir and lodgepole pine forests, ponderosa pine woodlands, Utah juniper-sagebrush scrub, and cottonwood bottomland.

Townsend's big-eared bat was historically added to the state SOC list, but the date and proximate reasons are undocumented. Townsend's big-eared bat was selected as a focal species to represent cave environments in forested habitats, due to the fact that it is a SOC with 87% of Montana serving as breeding range. Townsend's big-eared bat has been identified as an umbrella species for fringed myotis, spotted bat, and pallid bat.

No management activities specific to Townsend's big-eared bat are currently occurring in Montana. Maternity roosts and hibernacula should be routinely monitored to establish population trends across the state. Undiscovered maternity colonies and hibernacula undoubtedly exist in Montana.

Section 1 – General Information

Supporting Information

- Townsend's big-eared bat locations (see Section 2 for more information on location data).

Patch Delineation

- Townsend's big-eared bat patches delineated for this project represent the 20 largest areas of potential habitat.

- Habitat patches were obtained using a habitat suitability model developed in program Maxent (inductive) and reduced to the extent of the range of the species (as identified by the MNHP).
- Habitat patches may have been adjusted based on feedback from species experts**.**

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the % area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
    - The habitat suitability model adequately represents landscape conditions preferred by Townsend's big-eared bat.
    - The parameters listed in Section 3 for patch development generally represent Townsend's big-eared bat behavior.
    - The selected habitat patches include the largest and "best" areas supporting Townsend's big-eared bat.
- Assumptions associated with connectivity analysis.
    - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
    - Townsend's big-eared bats move into and out of the state along a generally north-south movement path.
    - Townsend's big-eared bat migration paths balance traveling the shortest distance with remaining over suitable habitat.
    - Townsend's big-eared bats can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment

A Maxent (inductive) model was used to develop a habitat suitability layer. This layer was used as input to model core areas and linkages.

- Habitat Suitability Model Inputs
    - Townsends Big-eared Bat locations
        - Locations were obtained from the Point Occurrence Database maintained by the Montana Natural Heritage Program. Locations were limited to those

associated with a spatial uncertainty smaller than 400m. A total of 126 locations were used for model training and 14 locations were used for model testing.

- Landscape variables used for the Maxent model are documented in Appendix D. Parameters were the same for all species.
- Habitat suitability model performance
  - Thirty replicate runs were performed. The average Area Under the Curve (AUC) for the 30 runs was 0.960 (std = 0.008). AUC = area under a curve obtained by plotting sensitivity (true positive rate) against 1-specificity (false positive rate) across all thresholds of a continuous model.

Section 3 – Habitat Patch Delineation

We used a patch tool provided by Corridor Designer (http://www.corridordesign.org) to determine areas that will be connected.

- Contiguous habitat patches were identified using parameters based on a brief review of the Townsend's big-eared bat literature (Gruver and Keinath 2003 and Schmidt 2003).
  - Model threshold (rescaled logistic threshold that represents the cutoff value between suitable and unsuitable habitat) = 66 (using rescaled Maxent model)
  - Perceptual distance (how far away is suitable habitat perceived) = 3200 meters (this is a representation of foraging distance)
  - Breeding patch size (minimum area needed to support breeding) = 6.6 ha (again based on foraging area not breeding patch size)
  - Population patch size (minimum area needed to support a population) = 33 ha (as per suggestion in the CorridorDesigner patch tool).
  - The 20 largest patches were used to represent the major areas supporting TBEBs.
  - Note that one patch is large enough that it spans the state -- it is a percolating patch.
- Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 20 patches. The 20 patches are now combined into 8 Regions.

Section 4 – Connectivity Analysis

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.
The following additional process steps were applied:

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with “most likely” connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.
- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated to connect to the boundary of the state limited to the portion that coincides with the range map of the species and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow the species to move across state boundaries to at least one (and quite often more) patch region(s).
- Two data sets were used to create the cost surface for this species: (1) the inverse of the habitat map (Maxent model) and (2) the Montana mountains grid. The MT mountains layer was adjusted so that any areas identified by the raw patch map were subset out and assigned a value of zero. The point was to set to no cost any area that the patch model indicated as "habitat" for the species.
- The MT mountains layer was assigned a multiplier value of 0.5.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review.

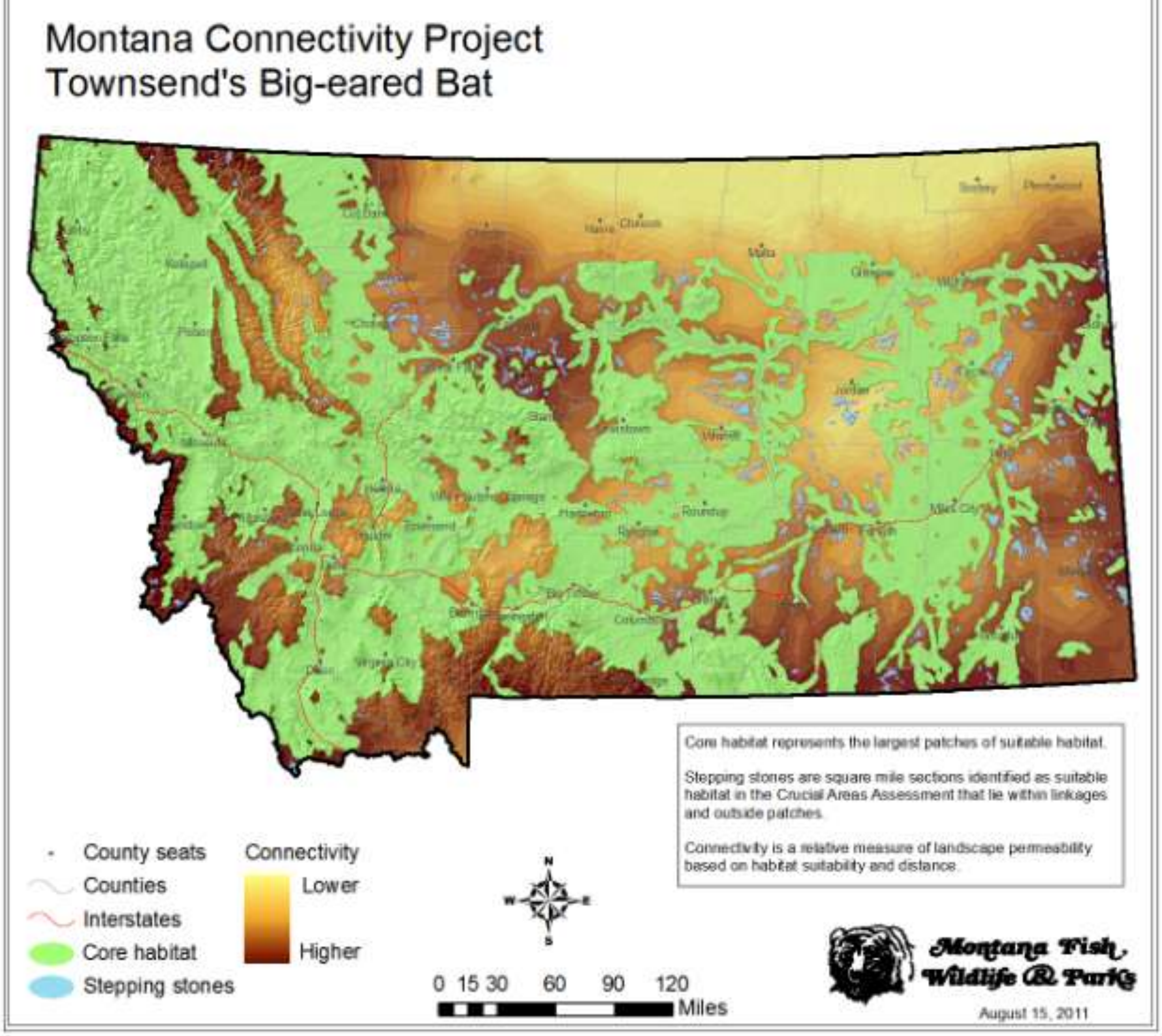


Figure 48. Townsend's Big-eared Bat core habitat and potential range/statewide landscape connectivity.

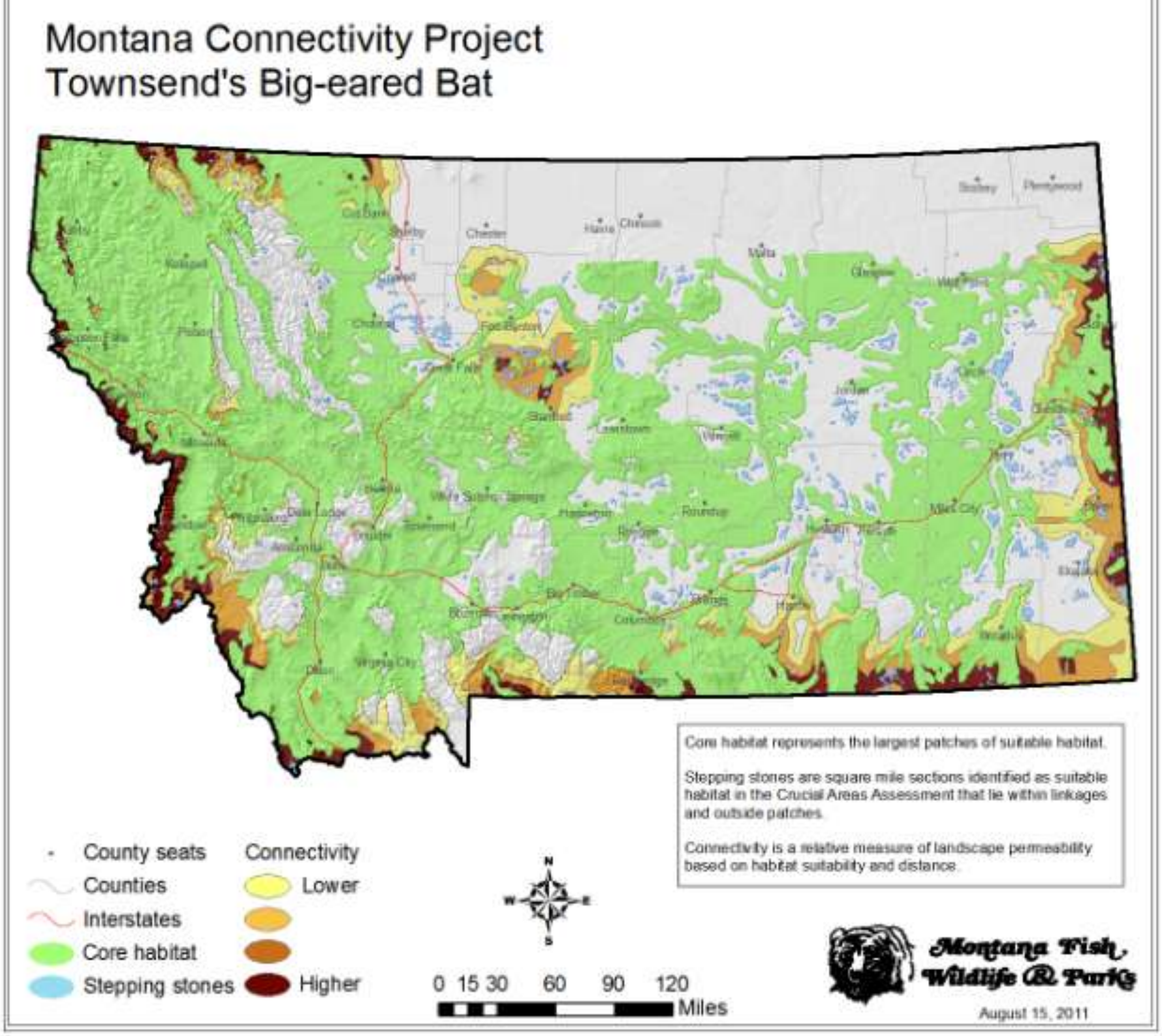


Figure 49. Townsend's Big-eared Bat core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.16 Trumpeter Swan (Cygnus buccinator)

Group: Avian

Ecosystem: Riparian/Wetland

Type of connectivity: Seasonal

Global/State Species of Concern Rank: G4/S3

Confidence Rating: Core (Medium) Connectivity (NE)

Figure 50. Trumpeter Swan Range

Introduction: Trumpeter swans that breed in Montana are non-migrants. They spend both the breeding season and the winter in southern Montana's lakes, ponds, and streams of the Red Rock Lakes National Wildlife Refuge. The Canadian subpopulation breeding in parts of British Columbia, Alberta, the Yukon, and the Northwest Territories will move south in late October to early November (Mitchell 1994). Trumpeter swan is commonly associated with Wetland and Riparian systems. The breeding habitat for Trumpeter Swans in the Red Rock Lakes/Centennial Valley of Montana includes lakes and ponds and adjacent marshes containing sufficient vegetation and nesting locations. Along the Rocky Mountain Front the breeding habitat is small pothole lakes, generally with sufficient water to maintain emergent vegetation through the breeding season (MTNHP 2003).

Trumpeter swan was historically added to the state SOC list, but the date and proximate reasons are undocumented. Trumpeter swan was selected as a focal species to represent conifer forest environments, due to the fact that it is a SOC with 9% of Montana serving as breeding range. Trumpeter swan has been identified as an umbrella species for common loon, American white pelican, tundra swan, northern pintail, harlequin duck, Franklin's gull, common tern, and black tern.

Management for trumpeter swans began in Montana in the early 1930's with the designation of Red Rock Lakes National Wildlife Refuge (RRLNWR). This refuge was specifically created for continued trumpeter swan presence and for active management practices. These early management practices consisted of protection from shooting, winter feeding stations, and relocation to other breeding locations (Mitchell 1994). Some of these management activities are still in practice today, along with others including habitat restoration, human recreation management, breeding, wintering habitat management, and winter translocation work (Mitchell 1994).

Section 1 – General Information
Supporting Information

- Trumpet swan locations (See section 2 for more information on piping plover locations).

Patch Delineation

- Patches were largely delineated by using the existing range map and adding polygons based on comments from reviewers and additional conversations with biologists.
- Habitat patches may have been adjusted based on feedback from species experts**.**

Connectivity Delineation

- Habitat patches were lumped into regions. Patches within 5 miles of each other were considered connected and assigned to the same patch region. All areas within 2.5 miles of a patch region are considered connected.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- Stepping stone habitat was identified by selecting all 1 square mile sections with greater than 50% suitable habitat based upon the suitability threshold referenced above. This is the same as was done to generate the CAPS layer for this SOC species, with the exception of the removal of agricultural lands before conducting the % area calculation.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - The habitat suitability model adequately represents landscape conditions preferred by Trumpeter swan.
  - The parameters listed in Section 3 for patch development generally represent Trumpeter swan behavior.
  - The selected habitat patches include the largest and “best” areas supporting Trumpeter swan.
- Assumptions associated with connectivity analysis.
  - Movement between stop-over and breeding sites is less influence by landscape conditions than the selection of those sites.
- Assumptions associated with linkage delineation
  - Trumpeter swans move into and out of the state along a generally north-south movement path.
  - Trumpeter swan migration paths balance traveling the shortest distance with remaining over suitable habitat.
  - Trumpeter swans can easily move within 2.5 miles of a habitat patch regardless of habitat quality.

Section 2 – Habitat Quality Assessment
In addition to the range map available from Natural Heritage, points from the tusw_PODLocs shapefile were used to digitize additional polygons.

Section 3 – Habitat Patch Delineation

- Digitized 5 new polygons to account for concentrations of observation points located in the Natural Heritage point shapefile, comments in the Base Camp discussion, and comments from FWP and FWS biologists (see below). These polygons were combined with buffered lakes\rivers as noted below.
- The final data set was created by merging these polygons with the swan distribution polygons in trsw_range_seasonal.shp.
- Applied a 0.5 mile buffer on Lake Koocanusa, Flathead River, Clark Fork River, Swan River, North Fork Flathead River, Noxon Reservoir, Cabinet Gorge Reservoir -- all these features were located in the TIGER_streams&lakes-hd43p data set.
- Applied a 1 mile buffer on the north shoreline of Flathead Lake -- found in the GER_streams&lakes-hd43a data set.
- As per conversations with Lynn Verlanic (FWS) and Gael Bissell (FWP).

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix F). The final layer consists of 14 patches.

Section 4 – Connectivity Analysis
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. Create Corridor Raster does the following:

- Generates cost-distance surfaces for each input source layer.
- Generates a corridor raster for each source layer pair specified in a custom text file.
- Combines corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for all corridor rasters.
- Slices the combined least-cost corridor raster into 20 5% slices.

This process was undertaken using either the range extent of the species or for the extent of the state. Raster slice maps were converted to vector format. The slice map was truncated at the number of slices that connect all core patches.

- Patches were lumped into regions using a 5 mile search distance. Patches within this search distance from each other were assigned to a common region and treated as a single source for subsequent cost-distance modeling.
- Corridor rasters were generated between patch regions with "most likely" connections. For example if patch 2 was positioned between patches 1 and 3 and the best available habitat would obviously guide movement through patch two as a connector, then corridors were generated between patches 1 and 2, and between patches 2 and 3, but not between patches 1 and 3.

- Portions of the north and south state boundary were clipped to the mapped range of the species to create two additional source polygons. This allows modeling potential linkage through the state for long distance migrants.
- Additional corridors were calculated between each of the border patches and each patch region in the analysis. This step is based on an assumption that all patch regions are potentially occupied so there must be at least one linkage that will allow birds to migrate from the state boundaries to each patch region.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.
- Stepping stones were delineated for bird species. Sections identified as suitable habitat in the Crucial Areas Assessment that fell within linkages and outside cores were designated as stepping stones. Such areas are available as potential stop-over locations for migrating or dispersing individuals.
- Linkage maps were submitted for review (Appendix F).

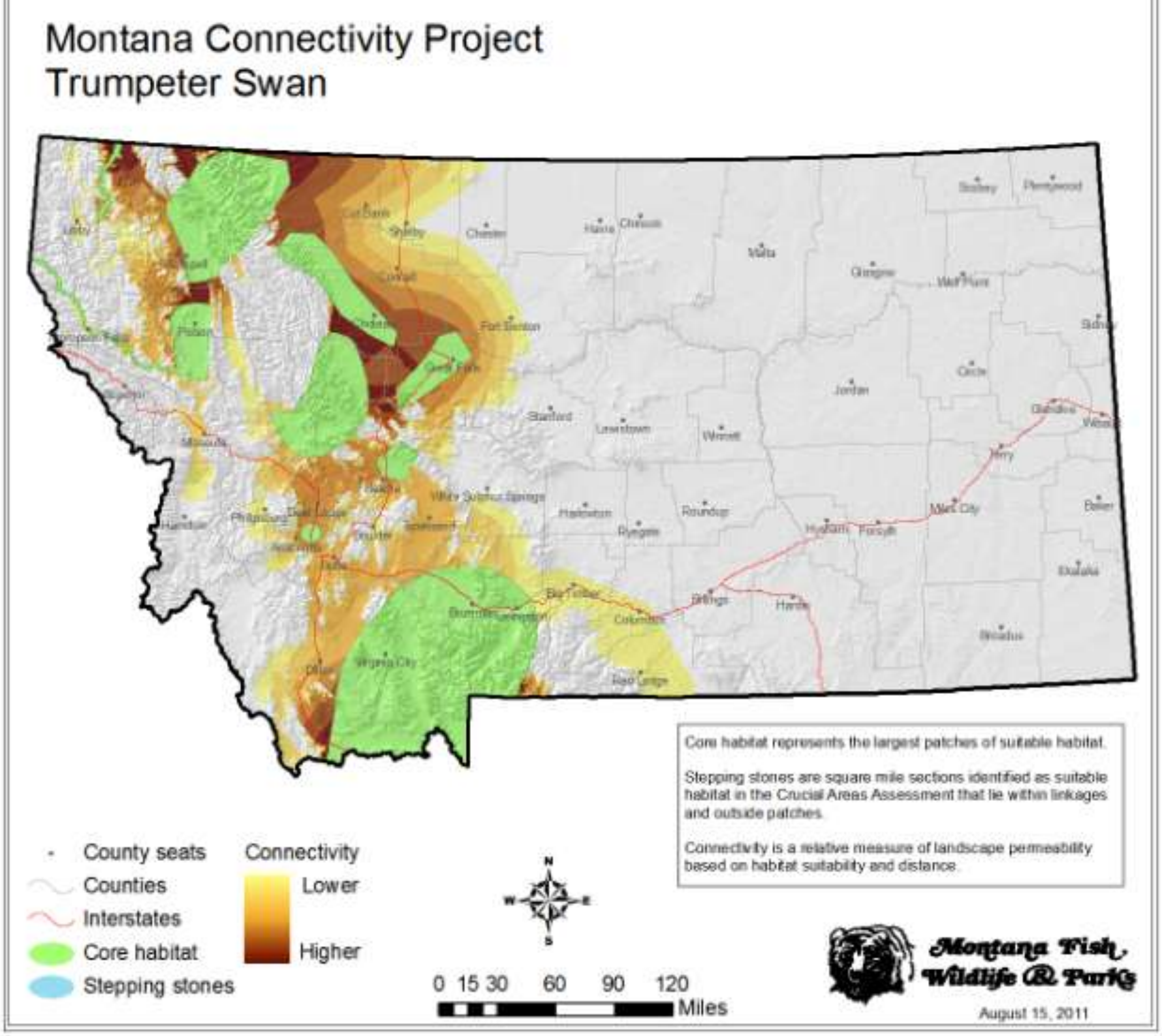


Figure 51. Trumpeter Swan core habitat and potential range/statewide landscape connectivity.

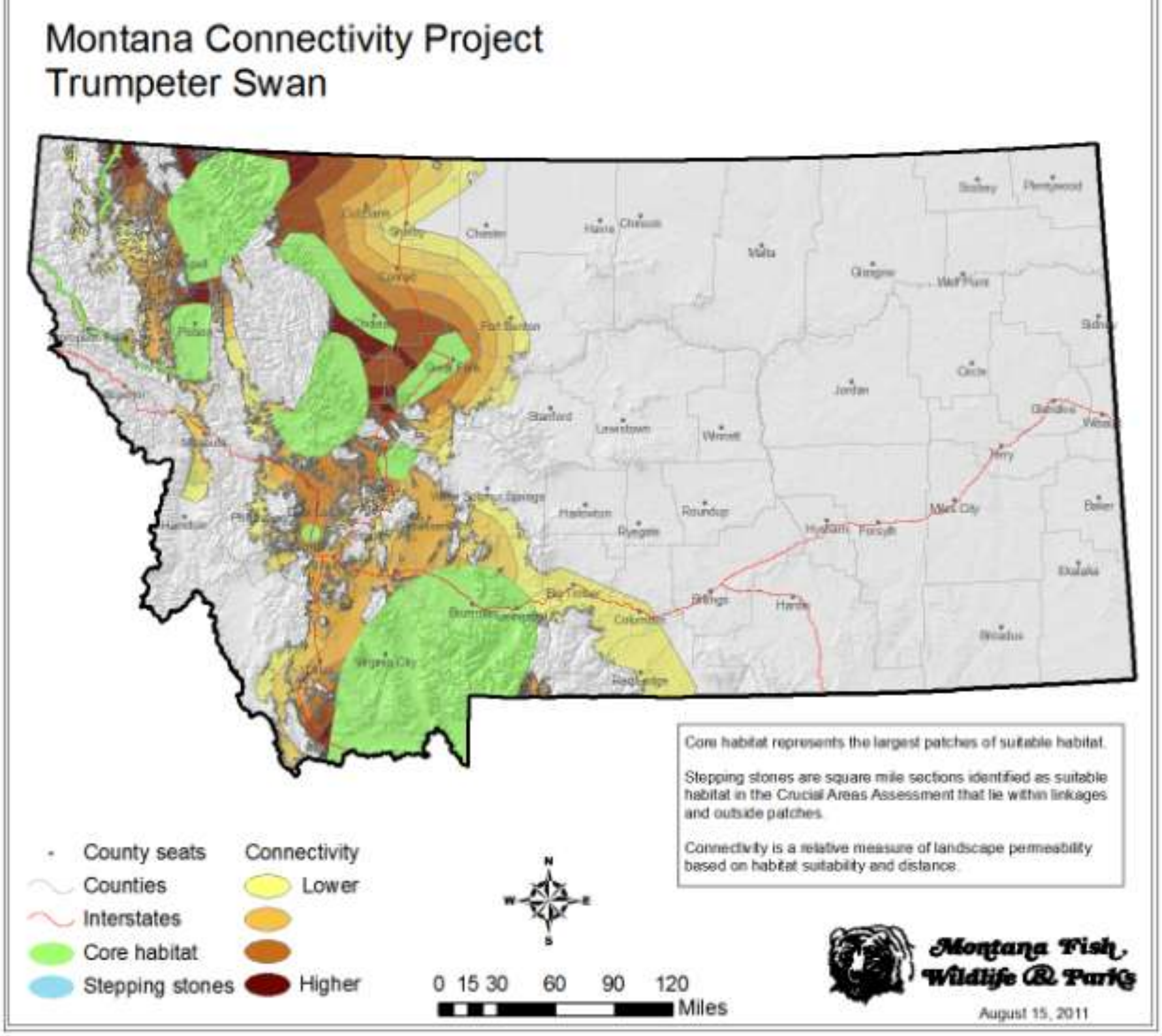


Figure 52. Trumpeter Swan core habitat and the minimum number of permeability slices needed to connect all habitat cores.

3.1.17. Wolverine (Gulo gulo)

Group: Mammal

Ecosystem: Forest and Woodland / Alpine

Type of connectivity: Long-term (genetic), Range expansion/shift

Global/State Species of Concern Rank: G4/S3

Confidence Rating: Core (High) Connectivity (Medium)

Figure 53. Wolverine Range

Introduction: Wolverine is a year-round resident of Montana. It is an elevational migrant, where seasonal ranges are within a large home range. Wolverine is commonly associated with Alpine, and Forest and Woodland systems. Wolverines are limited to alpine tundra, and boreal and mountain forests (primarily coniferous) in the western mountains, especially large wilderness areas. However, dispersing individuals have been found far outside of usual habitats. They are usually in areas with snow on the ground in winter. Riparian areas may be important winter habitat.

Wolverine was historically added to the state SOC list, but the date and proximate reasons are undocumented. Wolverine was selected as a focal species to represent conifer forest environments, due to the fact that it is a SOC with 37% of Montana serving as breeding range. Wolverine has been identified as an umbrella species for Canada lynx, fisher, grizzly bear, mountain lion, black bear, elk, mule deer, moose, wolf, bighorn sheep, hoary marmot, and ptarmigan.

Wolverines were nearly extinct in Montana during the early 1900's and have been increasing in numbers and range since. Recovery originated in northwestern Montana and subsequently spread to its current range (Newby and Wright 1955, Newby and McDougal 1964). On December 13, 2010, the U.S. Fish and Wildlife Service determined that the North American Wolverine occurring in the contiguous United States is a distinct population segment that warrants protection under the Endangered Species Act, but that listing the distinct population segment under the Act is precluded by the need to address other listing actions of a higher priority. Additional information on the species' management can be found on the U.S. Fish and Wildlife Service's Species Account: http://www.fws.gov/mountain-prairie/species/mammals/wolverine/

Section 1 – General Information
Background Information

- Core habitat and connectivity layers for wolverine have been obtained from the Wildlife Conservation Society (WCS). These layers are a result of ongoing work in the Greater Yellowstone Ecosystem by WCS Greater Yellowstone Wolverine Program, 2001-2009.

Patch Delineation

- Core habitat patches were identified by WCS and are referred to as Primary Wolverine Habitat.

Connectivity Delineation

- WCS utilized Circuitscape, a connectivity modeling technique, to predict linkage zones or connectivity areas among islands of primary wolverine habitat.

Assumptions:

- None Listed

Section 2 – Habitat Quality Assessment

- A habitat suitability model was developed using logistic regression analysis based on wolverine telemetry data collected in the Greater Yellowstone Ecosystem by the Wildlife Conservation Society's Greater Yellowstone Wolverine Program, 2001-2009. This modeling effort is being submitted for publication under the title "Developing a spatial framework for wolverine conservation in the western United States. The results are preliminary at this time.

Section 3 – Habitat Patch Delineation

- Using the wolverine model, all habitats above a specified resulting model threshold categorized as suitable for use by resident adult wolverines. These areas are referred to as "Primary Wolverine Habitat." A polygon layer representing primary habitat was made available to MFWP.

Section 4 – Connectivity Analysis

- A connectivity model was developed using a CircuitScape analysis to predict linkage zones or connectivity areas among islands of primary wolverine habitat. This analysis utilized the habitat suitability model layer as a base for the analysis. Primary habitat patches were "charged" based on their potential wolverine population capacity (using a density estimate within primary habitat). Charge was allocated among neighboring patches based on their distance from and exposure to the patch. This effort is being written up for submission to journal publication. The results are preliminary at this time.

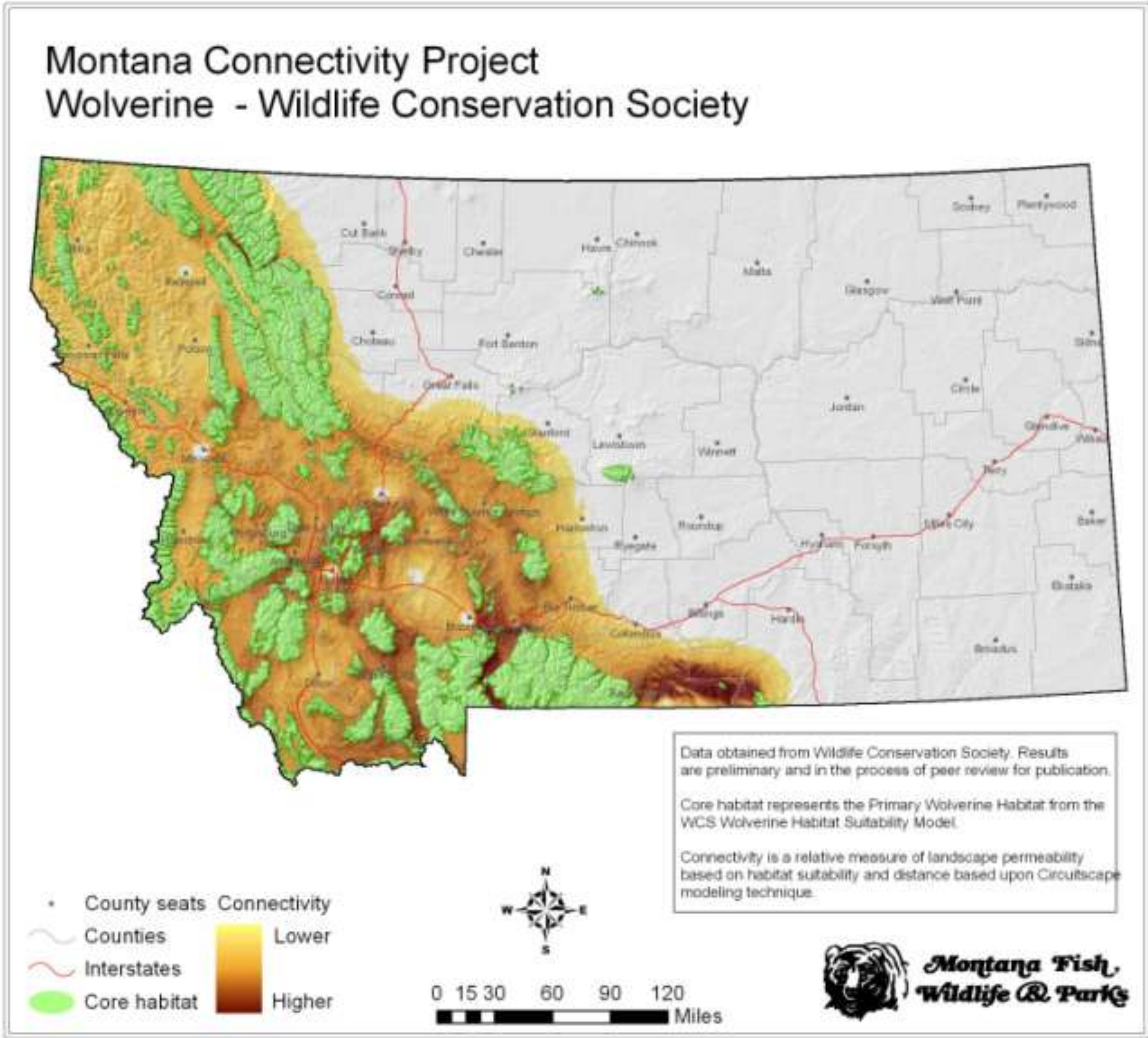


Figure 54. Wolverine core habitat and potential range/statewide landscape connectivity.

3.2. Species Guild Models

Species guild models were used to represent suites of focal species with generally similar patch and movement parameters and where individual behavioral responses were difficult to distinguish one from the other. Species Guild modeling followed the same process as individual species of identifying patches and running connectivity models between source and destination patches. We conducted guild modeling for two general groupings, Avian and Semi-aquatics. The avian guilds were further distinguished by group into Raptors, Shorebirds and Waterbirds. The modeling process occurred statewide, in some cases influence by factors beyond the border of Montana.

3.2.1. Avian Guilds

Generalized migration models were created to address avian species (Figure xx). These models were used to account for migrating species within 3 overall groups; water birds, shorebirds, and raptors. The models were based upon a variety of habitat characteristics used to approximate the cost of movement. Source and destination locations were compiled and the likely paths to connect these were identified using the path that minimized the overall habitat cost and distance moved.

3.2.1.1. Raptor Guild

Group: Avian

Ecosystem: Forest/Shrub/Grassland

Type of connectivity: Seasonal

Species Included: Ferruginous Hawk, Rough-legged Hawk, Swainson's Hawk

March 2011 © Peter LaTourrette

Confidence Rating: Core (NA) Connectivity (Low)

General Information

A generalized raptor migration model was created to address all raptor species (Appendix G). The model focused on broad winged soaring raptor species during the fall season. The model predicts raptor migration patterns by modeling patterns of mountain deflection updrafts across the state. Routes that provide contiguous strong updrafts along a north-south axis are predicted to provide the best routes for migrating raptors. The model does not include the influence of thermal updrafts which are also important for raptor migration. Thermal updrafts are created by differential heating of the earth's surface which is influenced by factors that can change between years and even days. The model also did not incorporate habitat associations based on land cover because we assume that raptors abandon their typical habitat associations during migration and select routes entirely based on air currents.

Assumptions

- Primary Axis of Movement (PAM) is generally N-S oriented.
- Deflection updrafts and thermals are primary determinant of movement cost. Thermals and updrafts oriented along PAM create least cost corridors for migration.
- Jet Stream position is useful indicator for direction of prevailing wind creating deflection updrafts.
- Habitat quality associations influence movement.

Habitat Quality

Habitat suitability was not developed for the raptor guild because raptors appear to suspend typical habitat selection during migration in favor of taking advantage of uplift air currents that facilitate gliding and soaring. Instead, a cost surface for connectivity analysis was based on topography (slope, aspect, and elevation change) in relation to assumed prevailing wind direction.

Habitat Patch Delineation

Source and destination patches outside the state boundaries were used for cost-distance modeling. These consisted of a patch along the US-Canada border extending from the eastern boundary of Montana to a point approximately 90 miles west of the western boundary of Montana, and a patch approximately 250 miles south of Montana extending from the intersection of Colorado, Nebraska and Wyoming to the Utah-Nevada border. Extending the model south and west of the Montana border allowed topography beyond the state boundaries to influence likely entry and exit location for migrating raptors (Figure 55).

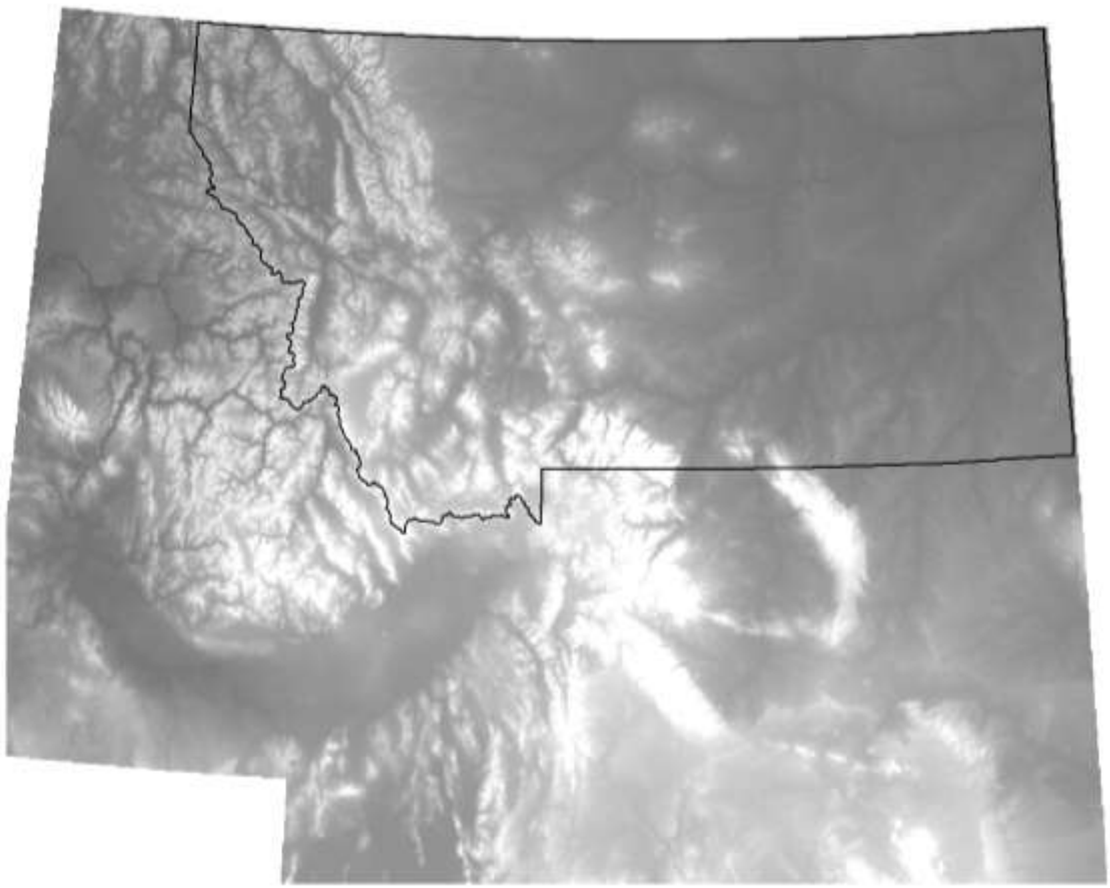


Figure 55. Analysis extent of raptor model

Connectivity Analysis

A cost surface was generated to predict the occurrence of deflective updraft currents likely to be used by raptors during migration. Areas with steep slopes, large changes in elevation over a small distance, and with aspects perpendicular to prevailing winds were assumed to produce the strongest deflective updrafts. Areas with highest potential for producing deflective updrafts were assigned the lowest cost values (Appendix G).

Connectivity Delineation

Connectivity results were reviewed by species experts and feedback documented.

Comments received from: Catherine Wightman (MFWP), Kristi Dubois (MFWP) and Amy Cilimburg (Montana Audubon)

- Model seems relatively weak relative to the known strength of the Rocky Mountain Front and known movement patterns in this area.
- Need to distinguish Spring from Fall movement
- Area from Big Belt Mountains to Bears Paw Mountains seems intriguing more research should look into the ability of this area to serve as a corridor

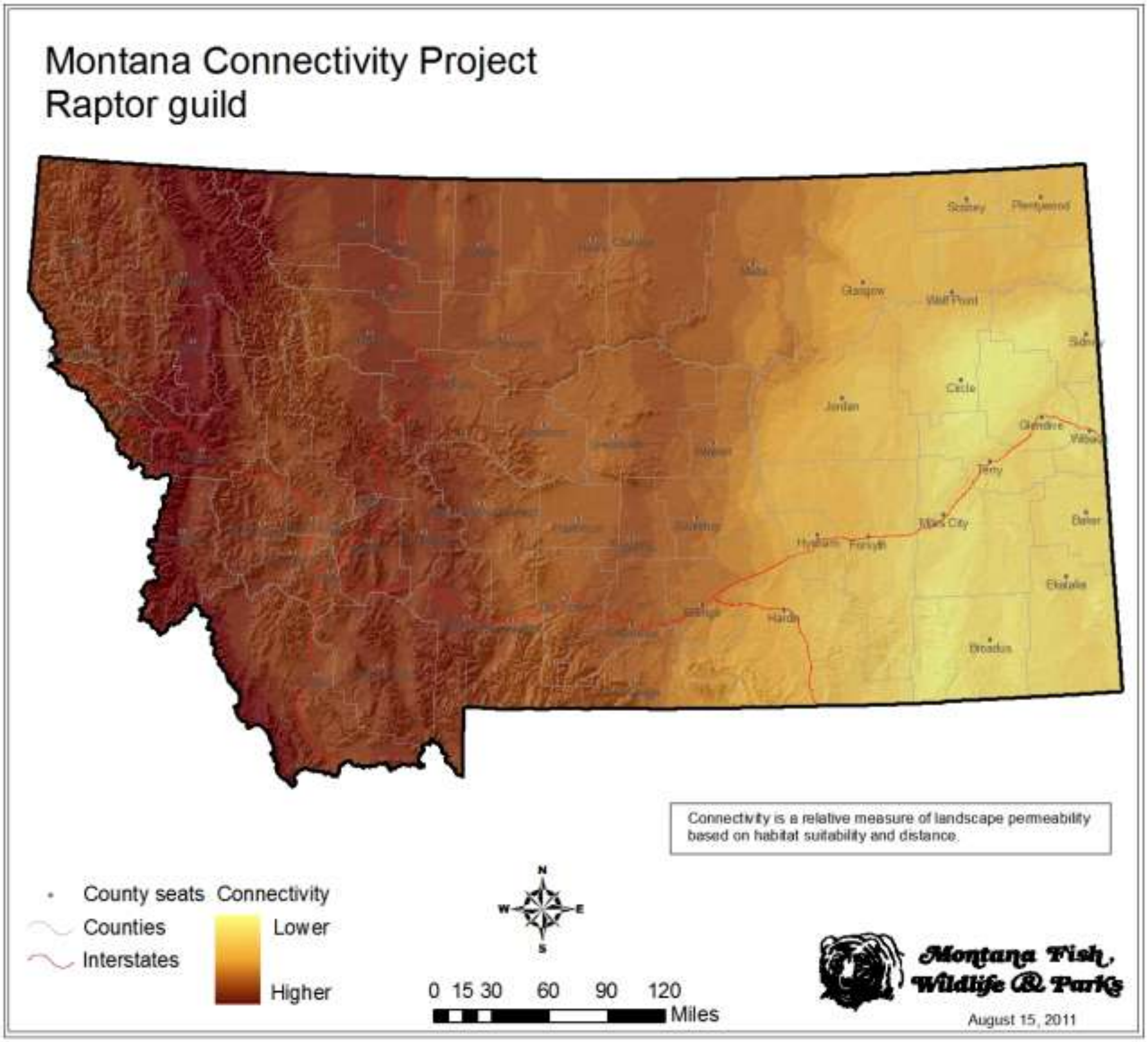


Figure 56. Raptor guild potential range/statewide landscape connectivity.

3.2.1.2. Shorebird Guild

Group: Avian

Ecosystem: Riparian/Wetland

Type of connectivity: Seasonal

Species Included: Long-billed curlew, Long-billed Dowitcher, Mountain Plover, Piping Plover

Confidence Rating: Core (NA) Connectivity (DNU)

General Information

A generalized shorebird migration model was created by lumping all shorebird species with similar habitat requirements into a single model. The model attempts to predict moderately fine scale movement patterns of shorebirds during seasonal migrations. These patterns were derived by incorporating the influence of habitat quality, topography, manmade hazards (tall towers), major staging areas, and general continental migration patterns into a cost-distance model.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - Species within the shorebird guild have similar habitat preferences which can be combined to produce a suitable generalized habitat model.
  - All major migration stopover/staging areas within Montana are known and represented in the patch layers used to generate models.
- Assumptions associated with linkage delineation
  - Shorebirds generally follow migration flyways delineated at a continental scale (see details in Section 4).
  - Major staging areas serve as stepping stones during migration.
  - Migrating shorebirds prefer to fly over suitable resting/feeding habitat.
  - Low altitudes impose fewer costs to migrating shorebirds than high elevations.
  - Seasonal wind patterns are not important because migrating birds adjust timing of flight to take advantage of circular wind patterns around weather fronts (e.g. fall migrants fly a day after passage of a cold front to take advantage of southerly tailwinds and clearing skies).

Habitat Quality

A generalized habitat suitability layer was created using habitat associations provided by Montana Natural Heritage Program. This layer was created as follows:

- Score each habitat type weighted by quality of association summed for all species in guild.
  a. High Quality = 3 pts; Medium Quality = 2 pts.; Low Quality = 1 pt.

b. Rescale scores 0-100 for each species so each species contributes equally to combined habitat scores.
c. Sum scores of all species within guild for each habitat type.
d. Invert values to create base cost layer.

Habitat Patch Delineation
Major staging areas were identified by soliciting information from waterfowl experts. Information provided was digitized in a GIS. In some cases, broad delineations of "important waterfowl areas" were restricted to include only areas within wetlands and/or National Wildlife Refuges or Wildlife Management Areas contained within the broader delineations provided by experts.

Connectivity Analysis
A cost surface was generated by modifying habitat suitability increasing cost for flying over high elevation areas or within 100 meters of a tower ≥ 200 ft. tall. Costs within major staging areas were reduced to zero.

To estimate the general direction of migration across Montana, maps of duck and goose corridors (Bellrose 1980) and "Areas of Continental Significance to North American Ducks, Geese, and Swans" (North American Waterfowl Management Plan, Plan Committee 2004) were compared to determine likely major points of origin or destination, and general direction of flight for birds flying across Montana. This information was used to identify segments of the Montana state boundary where birds flying from/to areas of continental significance were likely to cross the State line. The resulting patches were combined with major staging areas to use as source and destinations for the connectivity model. In addition, a major staging area was added to Idaho adjacent to the southwest border of Montana in approximately the Henry's Lake and Upper Snake River Plain areas.

We used a tool called Create Corridor Raster that was developed for this project to generate linkages.

- Major staging area patches within Montana with nearest distance values ≤ 20 miles were assigned to the same region and treated as a single habitat patch complex for subsequent processing.

- Corridor rasters were generated between patch regions with "most likely" connections. Most likely connections included border to border connections between patches described above plus connections to and between major staging areas within Montana likely to server as stepping stones along continental migration corridors.

- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.

- Linkage maps were submitted for review.

Connectivity Delineation

Connectivity results were reviewed by area biologists and feedback documented.

Comments received from: Jim Hansen (MFWP) and Robert Sanders (Ducks Unlimited)

- Do not recommend using this layer yet.
- Relative rankings make sense in light of techniques used, but do not accurately reflect known or perceived travel routes
- Misinterpretation of data and perceived strength of results, is likely for non-biologists and biologists without understanding of methods and could be problematic or dangerous relative to implementation of conservation efforts

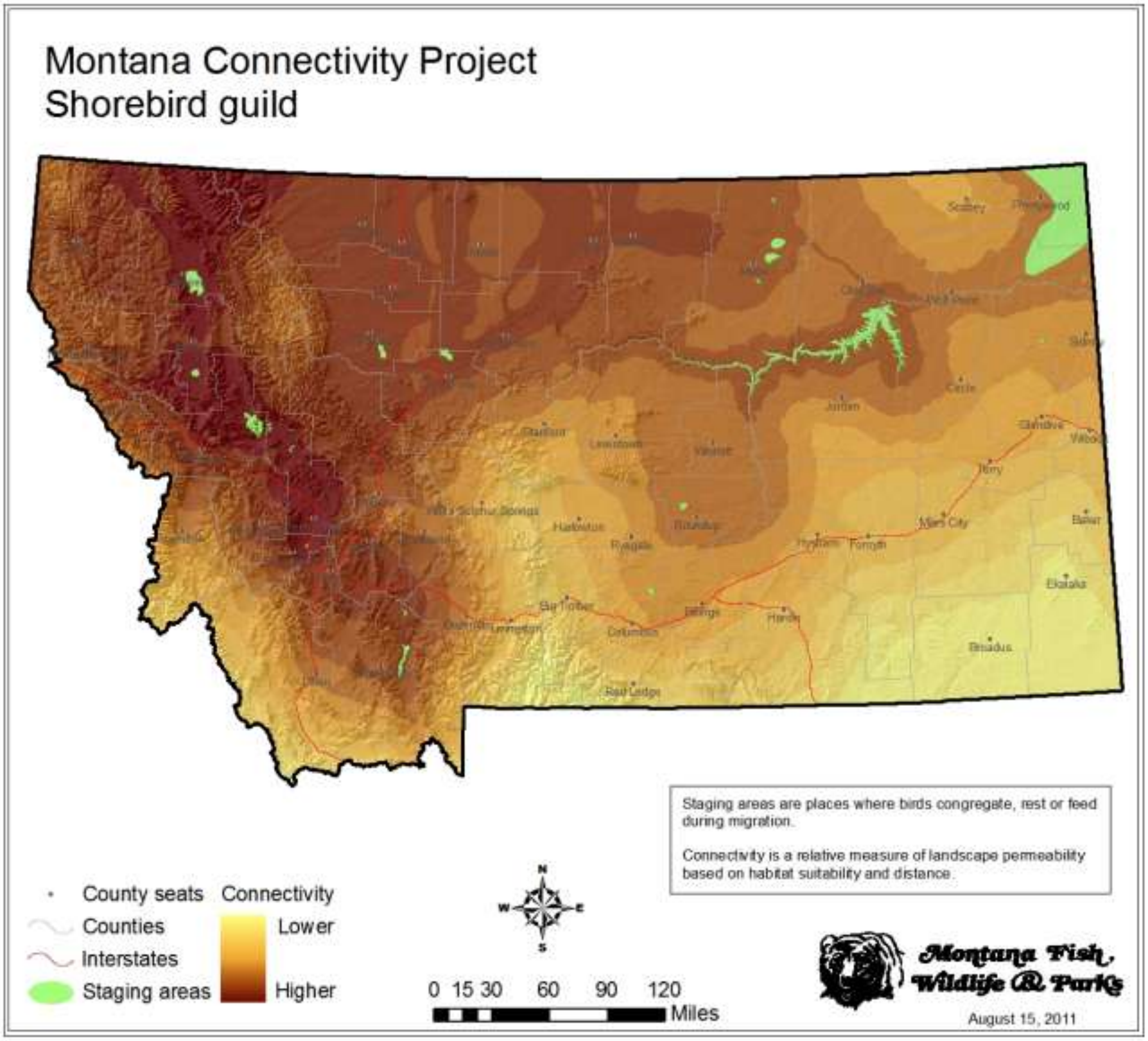


Figure 57. Shorebird guild staging areas and potential range/statewide landscape connectivity.

3.2.1.3. Waterbird Guild

Group: Avian

Ecosystem: Riparian/Wetland

Type of connectivity: Seasonal

Species Included: American White Pelican, Black Tern, Common Loon, Common Tern, Franklin's Gull, Northern Pintail, Trumpeter Swan, Tundra Swan, and Wilson's Phalarope

Confidence Rating: Core (NA) Connectivity (DNU)

General Information

A generalized water bird migration model was created by lumping waterfowl and other migratory bird species with similar habitat requirements into a single model. The model attempts to predict moderately fine scale movement patterns of water birds during seasonal migrations. These patterns were derived by incorporating the influence of habitat quality, topography, manmade hazards (tall towers), major staging areas, and general continental migration patterns into a cost-distance model.

Assumptions:

- Assumptions associated with habitat and patch delineation
  - Species within the water bird guild have similar habitat preferences which can be combined to produce a suitable generalized habitat model.
  - All major migration stopover/staging areas within Montana are known and represented in the patch layers used to generate models.
- Assumptions associated with linkage delineation
  - Water birds generally follow migration flyways delineated at a continental scale.
  - Major staging areas serve as stepping stones during migration.
  - Migrating water birds prefer to fly over suitable resting/feeding habitat.
  - Low altitudes impose fewer costs to migrating water birds than high elevations.
  - Seasonal wind patterns are not important because migrating birds adjust timing of flight to take advantage of circular wind patterns around weather fronts (e.g. fall migrants fly a day after passage of a cold front to take advantage of southerly tailwinds and clearing skies).

Habitat Quality

A generalized habitat suitability layer was created using habitat associations provided by Montana Natural Heritage Program (MNHP). This layer was created as follows:

- Score each habitat type weighted by quality of association summed for all species in guild.
    a. High Quality = 3 pts; Medium Quality = 2 pts.; Low Quality = 1 pt.
    b. Rescale scores 0-100 for each species so each species contributes equally to combined habitat scores.
    c. Sum scores of all species within guild for each habitat type.
    d. Invert values to create base cost layer.

Habitat Patch Delineation

Major staging areas were identified by soliciting information from waterfowl species experts and digitized. In some cases, broad delineations of "important waterfowl areas" were restricted to include only areas within wetlands and/or National Wildlife Refuges and/or Wildlife Management Areas contained within the broader delineations provided by experts.

Connectivity Analysis

A cost surface was generated by modifying habitat suitability increasing cost for flying over high elevation areas or within 100 meters of a tower ≥ 200 ft. tall. Costs within major staging areas were reduced to zero.

To estimate the general direction of migration across Montana, maps of duck and goose corridors (Bellrose 1980) and "Areas of Continental Significance to North American Ducks, Geese, and Swans" (North American Waterfowl Management Plan, Plan Committee 2004) were compared to determine likely major points of origin or destination, and general direction of flight for birds flying across Montana. This information was used to identify segments of the Montana state boundary where birds flying from/to areas of continental significance were likely to cross the state line. The resulting patches were combined with major staging areas to use as source and destinations for the connectivity model. In addition, major staging areas in Idaho, Utah, and Wyoming were included as source areas by extending the cost surface approximately 100 miles to the west, and 200 miles to the south of the Montana border. Costs outside the Montana boundary were estimated based on elevation only. This provided a general estimate of the influence of topography on migration paths between major staging areas outside the Montana boundary and the State line.

The "Create Corridor Raster" tool that was developed for this project was used to generate linkages.

- Major staging area patches within Montana with nearest distance values ≤ 20 miles were assigned to the same region and treated as a single habitat patch complex for subsequent processing.

- Corridor rasters were generated between patch regions with “most likely” connections. Most likely connections included border to border connections between patches described above plus connections to and between major staging areas within Montana likely to server as stepping stones along continental migration corridors.

- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for all linkage combinations calculated. This map was subdivided into 5% intervals and truncated to retain the fewest intervals needed to provide at least one linkage to each habitat patch region.

Connectivity Delineation

Connectivity results were reviewed by area biologists and feedback documented.

Comments received from: Jim Hansen (MFWP) and Robert Sanders (Ducks Unlimited)

- Do not recommend using this layer yet.
- Relative rankings make sense in light of techniques used, but do not accurately reflect known or perceived travel routes
- Misinterpretation of data and perceived strength of results, is likely for non-biologists and biologists without understanding of methods and could be problematic or dangerous relative to implementation of conservation efforts

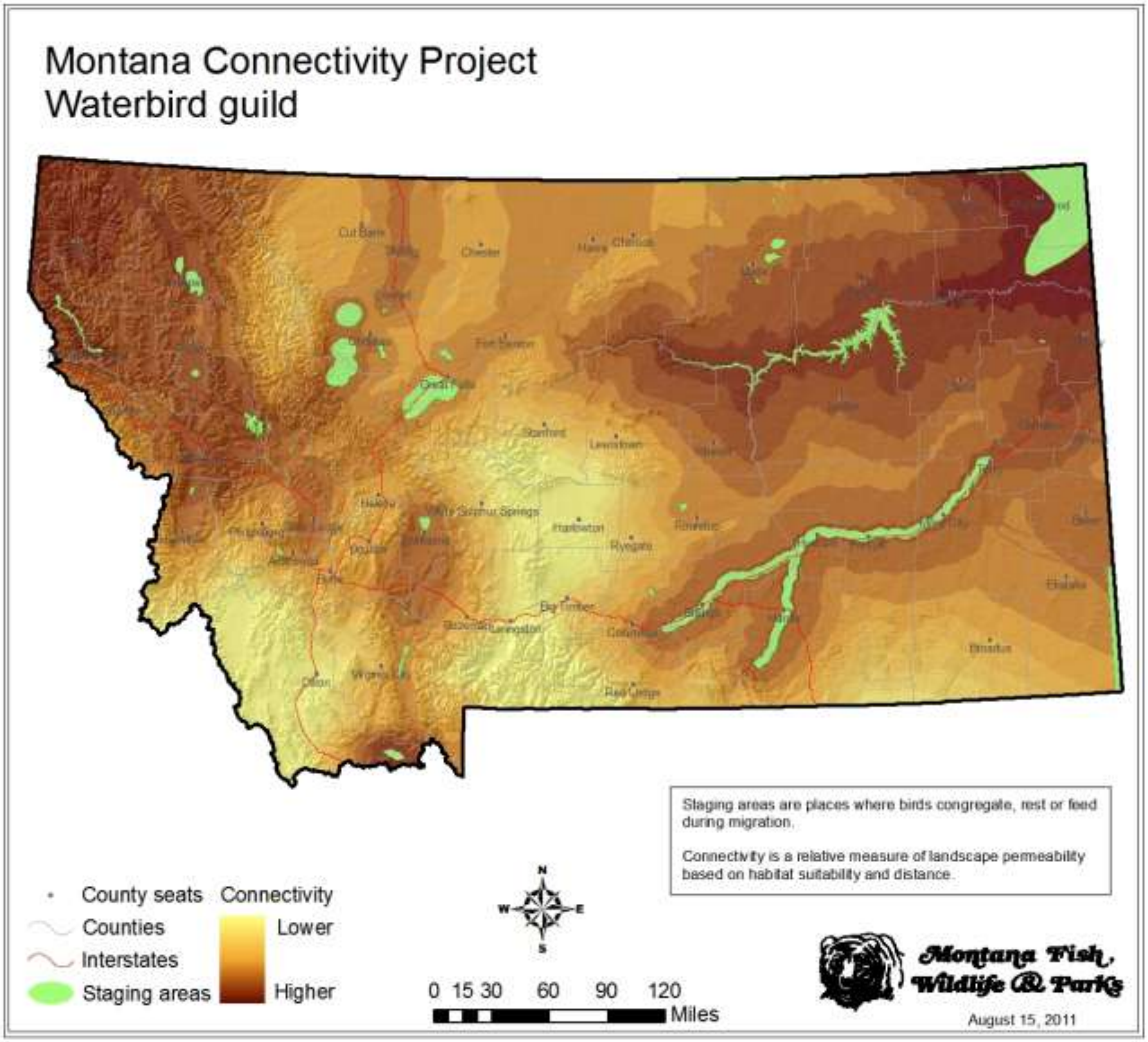


Figure 58. Waterbird guild staging areas and potential range/statewide landscape connectivity.

3.2.2. Semi-aquatic Guild

Group: Semi-aquatics

Ecosystem: Riparian/Wetland

Type of connectivity: Seasonal

Species Included: Beaver, Northern River Otter, Spiny-softshell Turtle

Confidence Rating: Core (NA) Connectivity (Low)

General Information

Riparian and wetland systems are some of the most biologically diverse ecological systems and typically support high densities of species. Often referred to as “ribbons of life” in a relatively dry prairie environments, riparian and wetland systems are also among our most impacted by human development. Semi-aquatic species conduct much of their life history, including dispersal and seasonal movements, in and adjacent to water.

Semi-aquatic focal species included Northern River Otter, Beaver, and Spiny Softshell turtle. These species were selected to represent the various drainage systems in Montana. Northern River Otter is a resident species occurring over much of the western 2/3 of the state. It has a rank of S4 in Montana’s Species of Concern (SOC) listing. Beaver is widespread, common and mobile species occurring in and along waters across the entire state. It has a ranking of S5 in the Montana’s SOC listing. Spiny Softshell turtle is a riverine dependent species. It has a S3 ranking in the Montana’s SOC The model is probably weakest for this species as it is thought to be much less mobile on land than the other two species described.

Given the existing knowledge, broad distribution and relative terrestrial mobility Beaver were used as the primary source of parameters for modeling. For Beaver specifically, most activities outside of water occur within about 100 m of stream or lake shores. However, there are occasional movements that take individuals outside this narrow terrestrial buffer. A generalized permeability model was created by treating the semi-aquatic species as a group within a single modeling approach. The model attempts to predict permeability of the landscape between areas of suitable habitat generally associated with riparian systems. While some behavioral variability will exist in movement patterns and associated response to various costs of that movement, known information was generalized for these species. The connectivity model we developed is designed to accommodate these movements by capitalizing on known bio-physical and habitat preferences.

Assumptions:

- The habitat suitability/cost model adequately represents landscape conditions preferred by these species.
- The parameters listed in Section 3 for patch development generally represent these species behavior.
- The selected habitat patches include the largest and “best” areas supporting these species.
- Movement will be between adjacent hydrologic units and not subject to influence from habitat patches or costs in other areas.

Habitat Quality

Habitat cores were created by buffering lakes and perennial streams by 100 m. The data set was refined to only include those buffered polygons where land cover was neutral or beneficial.

Habitat Patch Delineation

Patches were delineated by incorporating areas of the landscape comprising specific land cover characteristics that fell within a 100 m buffer of perennial streams and lakeshores.

Patches were reviewed by area biologists and feedback indicated patches appeared reasonable and no adjustment was necessary. Comments were received from: Andrew Jakes (student, University of Calgary), Bryce Maxell (MNHP).

Connectivity Analysis

The cost surface, which forms the basis of connectivity modeling, was the result of an additive raster model. Costs were imparted to specific landscape features. Where such features were assumed to be beneficial to semi-aquatic species costs were assigned low values. Where features were assumed to be neutral or not useful, costs were assigned higher values. The following provides a summary of the layers and attributes included in the connectivity modeling analysis:

- Land cover was reclassified to reflect types that were beneficial, neutral, or not useful. Beneficial types included land cover classes such as cottonwood, aspen, and wet meadow. Types that were not useful included land cover classes such as cliffs, scree, bare rock, and snow. Neutral types included all other land cover classes.
- Slope was reclassified to reflect flatter areas (0-15%) as being more beneficial than steeper areas (15-45% and > 45%) of the landscape.
- A flow accumulation grid was created to reflect portions of the landscape where water was more likely to flow. The idea behind including this landscape feature was that semi-

aquatic species would prefer to move along streams or drainages than across open areas of the landscape. Higher flow accumulation values indicated areas more beneficial to movement than lower flow accumulation values.

- Euclidian distance was calculated from lakeshores and perennial streams. Areas of the landscape closer to these features were more beneficial than areas further away.

Connectivity Delineation

- Connectivity was determined by running connectivity models between patches in adjacent 5th code hydrologic units.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.

Connectivity results were reviewed by area biologists and feedback indicated connectivity appeared reasonable and no adjustments were made.

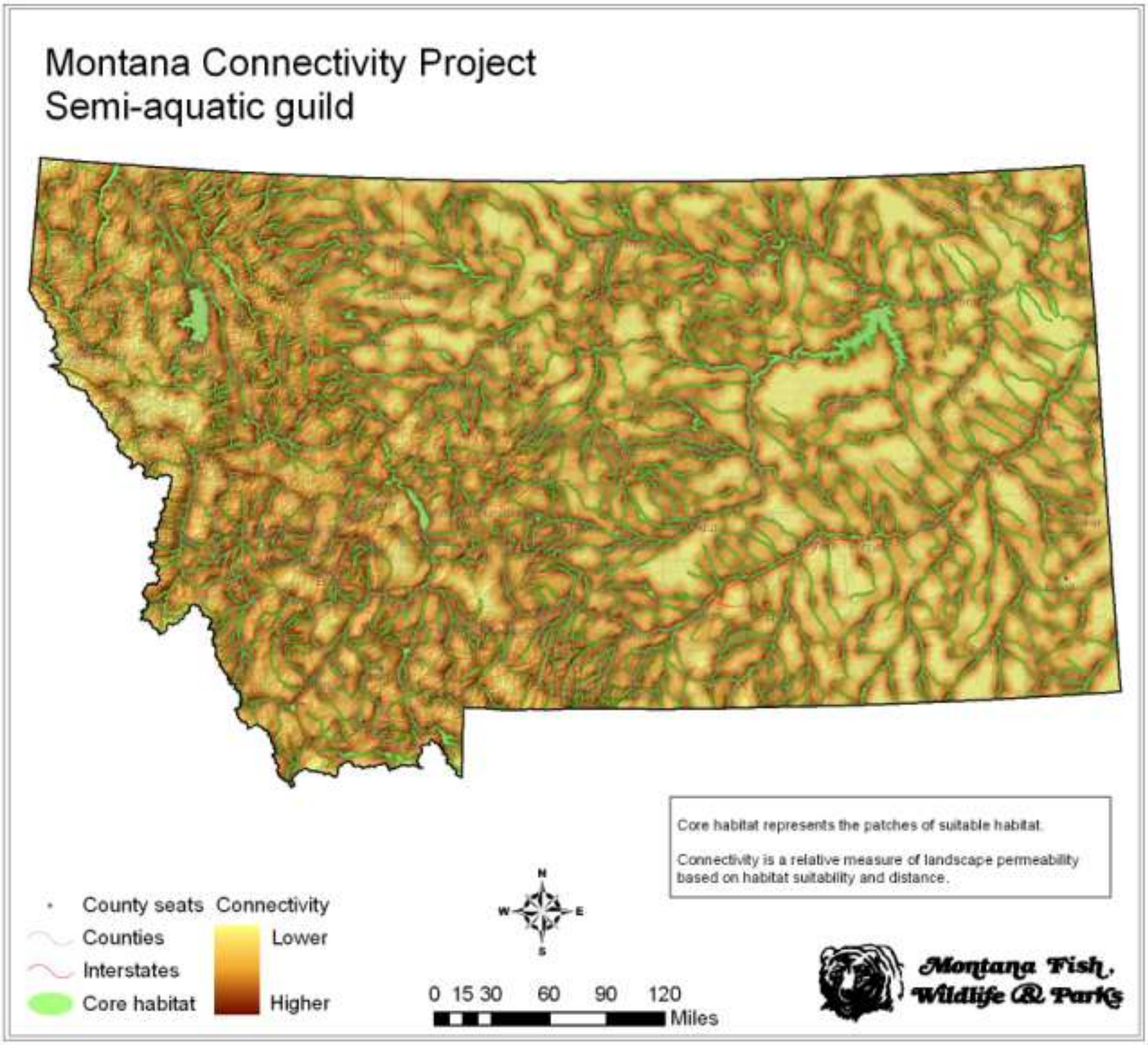


Figure 59. Semi-aquatic guild core habitats and potential range/statewide landscape connectivity.

3.3. Landscape Block Based Species Models

3.3.1. Large Intact Landscape Block Generation

<u>Methods</u>

MFWP used a landscape integrity approach to identify large areas of native habitat that served as source and destination patches for a variety of game and non-game species. The resulting "patches" have been labeled Large Intact Landscape Blocks (LILB).

Identifying "native" land cover (Appendix H Table 1) using the Montana Land Cover layer (MNHP) was the initial step in conducting the LILB analysis. We eliminated all cover types that are non-native cover types with the exception of open water and the harvested forest classes. We removed polygon, linear, and point features from the remaining native cover after buffering each feature by one cell at 100 meter resolution (Appendix H Table 2). Finally, we passed a 20 x 20 cell moving window over the entire raster layer, identifying cells that had at least 90% of this window area as "native" cover and that have not been impacted by these other human-caused alterations. See Appendix H for geoprocessing steps.

<u>Results</u>

Size of Blocks

Five hundred and fifty-five blocks resulted from the process (Figure 60). For the purposes of characterizing some of the blocks we divided the state into west and east, which generally described Montana's mountains and plains, respectively. The blocks ranged in size from 10,000 acres (15 sq. miles) to 2.8 million acres (4405 sq. miles). The majority of the blocks are less than or equal to 32 square miles in size. The largest blocks are associated with Glacier National Park (and associated wilderness areas to the south), the Charlie M. Russell National Wildlife Refuge, and the Absaroka-Beartooth Wilderness Area. The distribution of block sizes statewide, for the west, and for the east tend to center around fifty square miles, and all three distributions have a large number of outliers, even with the largest four blocks removed.

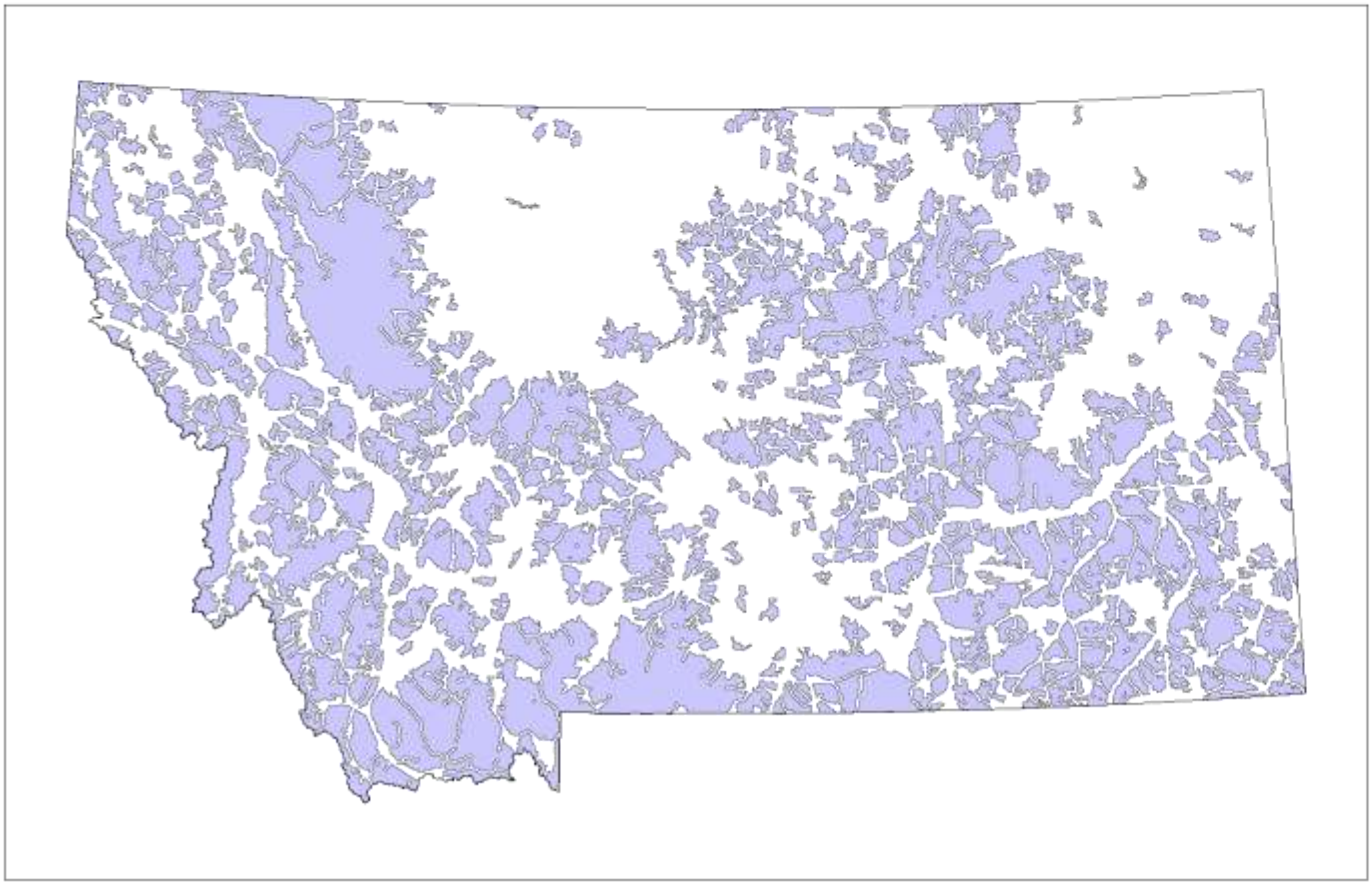


Figure 60. Large intact landscape blocks (n=555).

Elevation of Blocks

The mean elevation for blocks statewide is 4149 feet, for blocks in the west it is 5309 feet, and for blocks in the east it is 3206 feet. These figures compare to a mean elevation of 4132 feet statewide, 5225 in the west, and 3047 in the east. Blocks tend not to include features such as major rivers and towns because these features typically occur in low-lying areas where human development which were excluded by the moving window analysis.

Land cover

We classified the Montana Land Cover into nine classes to help characterize the landscape blocks: water, developed or altered, agriculture, barren lands, forest, shrubland, grassland, harvested or burned forest, and riparian or wetland. We calculated the percent cover of each of these cover types by block. Blocks tend to have more forest cover in both the west and the east than the background at large and areas that are not contained in blocks. In the east the blocks are composed of a higher percentage of shrub cover than the background and areas not in blocks,

blocks in southwest Montana also have a high percentage of shrub cover, but do not differ as much from the background areas in terms of amount of shrub cover. In the west, blocks have a lower percentage of grassland cover than the background and areas not in blocks, whereas in the east the relationship is the opposite. Blocks with a high degree of grassland cover are found along the Rocky Mountain Front, the Hi-Line, near the Confederated Salish and Kootenai Tribal Land in western Montana, and in southeast Montana. Barren lands (including cliffs and alpine areas) do not make up a large percentage of blocks with the exception of blocks around the CMR and near Glacier National Park.

Discussion

LILB are areas where the direct effects of the "human footprint" are least. We have defined "large" to mean > 10,000 acres. We have defined "intact" to mean "natural" cover types with little human intrusion. We have defined "blocks" to mean contiguous areas as indentified by our moving window. All else being equal, smaller areas hold smaller populations (Soule 1987). Smaller areas tend to have fewer species (MacArthur and Wilson 1967). The size of an area has a pronounced effect on the viability of species and ecological processes (Noss 1995).

3.3.2. Large Landscape Blocks Species Models

General Information

Species in this group included Black Bear, Canada Lynx , Elk, Grizzly Bear, Moose, and Mountain Lion, Mule Deer, and Pronghorn. These species were assessed for linkages to produce a layer of habitat connectivity based upon expert opinion, and also modeled using LILBs for source and destination habitat patches and similarly generated cost surfaces.

Expert Delineations

In the species specific expert delineation mapping process, the following types of connectivity were identified by FWP biologists for each species in this group:

- Linkage or corridor
  - Connection between two separate herd units or populations (e.g., movement between mountain ranges).
  - Connection between distinctly separate core habitats of a single population (e.g., movement between summer range and winter range).

        - ***Note***: Several respondents have used the term “Key Linkage Area” to further highlight areas particularly important to a population or used by multiple species.
- Transitional Range
    - Area between core summer and core winter range within a continuous herd unit, that is used during spring/fall and into the other seasons depending upon conditions. These areas exhibit a gradient of use throughout the year.
- Dispersal
    - An area that allows movement of individuals expanding into new territory or serves to facilitate movement for genetic exchange between existing populations.
- Diffuse
    - Unstructured movement, a random pattern that may or may not be seasonal. An area where movement is important within a specific season or may occur year round.
- Undefined
    - An area where the biologist has concerns about activities disrupting species movement, but is uncertain about what type of movements occur.
- Impeded
    - Areas where movements of animals have been restricted or impeded. This may be a complete or partial restriction.

The areas were delineated by on-screen or hard copy digitizing. There were no limitations placed on where the delineation could occur. The resulting layer varied in it completeness across Montana. Many areas, known by biologists to potentially have movement corridors, could simply not be delineated due to lack of knowledge. Due to the limitations in this layer we attempted to support this technique with the landscape block process.

Large Intact Landscape Blocks Method

The LILBs were used as the geographic basis to generate cores for the big game species and delineate connectivity between these cores. Each species was categorized as to how they used the identified LILBs either as a generalist, primarily forest or primarily grass/shrub (Appendix I). All LILB were used for the “generalist”. For the forest category, all non-forest habitat classes were considered “non-native”. For the grass category all non-grass/shrub habitat classes were considered “non-native”. LILB’s of an area of 5000 acres or more were utilized for the process. All areas overlapping distribution were included in the process, including areas within National Parks and Indian Reservations.

Cost surfaces were generated using the same layers as used to identify anthropogenic features for the LILB's, with associated costs occurring on a 0 (lowest cost) to 100 (highest cost) scale (Table 7). In addition, habitat costs varied between general, primary forest, and grass shrub species. Core to core connections were then modeled using the same technique as the species specific models. However, by this time in our work model code had been refined to increase efficiency, and that allowed us to model many more core-core pair connections than previously possible.

The resulting connectivity grid for each pair connection was first limited to the best (lowest) 20% of the values for that connection before being mosaiced to the statewide connectivity layer for that species. This alleviated problems whereby lower costs due to cores within close proximity did not overwhelm, or falsely represent, areas beyond the most likely area of connectivity for that pair. This process allowed us to generate connections within a certain distance threshold and combine them with connectivity surfaces for broader areas which we termed "regions". These connections are referred to as core (local) and regional connections. The regional connections process combined core patches within a specified distance into a single region and then connected that region to others using the standard connectivity modeling process. The resulting connectivity layer subsequently represents connections at two scales, local and regional, and presents them on the same relative scale for each species. Regional connections tend to represent higher costs and this pattern can be seen in the results. The resulting surface was then split into 100 even 1% slices.

Anthropogenic Features Cost	At Location	100 - 500 m	500 - 1000 m	> 1000 m
Buildings/Towns				
Incorporated Areas (City/Town Limits)	100	80	60	0
Structures (All Buildings)	90	60	30	0
Roads				
Interstates / Major Highways	90	75	50	0
Other Paved Routes	75	50	25	0
Graded Roads/Railroads	60	30	0	0
Local Roads	25	15	0	0
Other Infrastructure				
Coal Mine / Pit Mine	100	75	30	0
Gravel Pit / Landfill	90	30	0	0
Oil and Gas Wells	75	50	25	0
Wind Turbines	75	50	25	0
Ski Areas	75	50	25	0
Superfund Sites	60	30	0	0
FCC Towers / Electric Lines	40	20	0	0

Landcover Costs	General Model	Forest Preference	Grass/Shrub Preference
Developed	100	100	100
Developed Open Space/Water	75	75	75
Cultivated Crop	50	50	25
Rock/Wetlands	25	25	25
Pasture/Hay	25	25	10
Forest (inc. Riparian Forest Shrub)	5	5	50
Grass/Shrub	5	20	5
All Other Classes	5	5	5

Table 7. Costs associated with different types of habitats and human infrastructure.

Mapping Process

- Processing Note: All LILB cores were simplified using Point Remove with 200m maximum distortion
- Areas within National Parks and Indian Reservations were included, even though MFWP distribution layers do not extend into these areas.
- Connectivity results were briefly reviewed by area biologists. While reviewers generally think the LLB technique has merit more work needs to be done. (Appendix I)
- These species models were developed prior to the ecosystem based connectivity efforts. Due to improvements in the models that may more accurately reflect the above species, these older models may be out of date and not applicable. If accommodations for species specific distribution are needed after review of these data, then future revisions may occur. For now these models should be considered as an older version than the ecotype models described in the following section. See Appendix J for updated costs.
- See Appendix K for all specifics regarding numbers of cores, regions and analysis distance for each.

3.3.2.1. Black Bear (Ursus americanus)

Group: Mammal

Ecosystem: Forest Generalist

Type of connectivity: Within season, Seasonal, Long-term

Economically Valued Species

Confidence Rating: Core (Low) Connectivity (Medium)

Figure 61. Black Bear Range

Introduction
Black Bear are a resident terrestrial species considered a forest generalist that can be found across forest habitats primarily in western forest and into the southeastern portion of Montana. This species was selected as a focal species to represent primarily forest and woodland habitats and due to its economic value to the state as a game species.

Supporting Information
- Species distribution - Expert knowledge layer maintained by MFWP biologists, available at: http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html

Patch Delineation
- 185 LILB Cores – Within western Montana, all core patches of Forest LILB's overlapping this species distribution were selected, as well as, all other forest core patches within Indian Reservations and National Parks. In the some areas without sufficient core forested habitat the island mountain ranges identified as having black bear distribution were included, such as the Judith and Moccasin mountains.

Connectivity Delineation
The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:
- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
  - Local Scale
    - Pairwise comparisons of a source patch to all other patches within 25 km
      - Distance based upon visual estimation to connect core patches
    - 612 Local core patch pairs were identified
  - Regional Scale

        - Regions were created by combining all core patches with edges within 15 km of any adjacent patch
        - 16 Core patch regions were identified
        - Pairwise comparisons of a region to all other regions within 150 km
            - Distance based on furthest distance to connect most isolated island mountain ranges
        - 57 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
    - Generated a single corridor raster for each source layer pair within an analysis extent of 10 km beyond the greatest extent of the patch pair and 20 km beyond the greatest extent of the regional patch pair
    - Selected the 20% lowest cost distance values for each pair for combination
    - Combined all individual pair corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

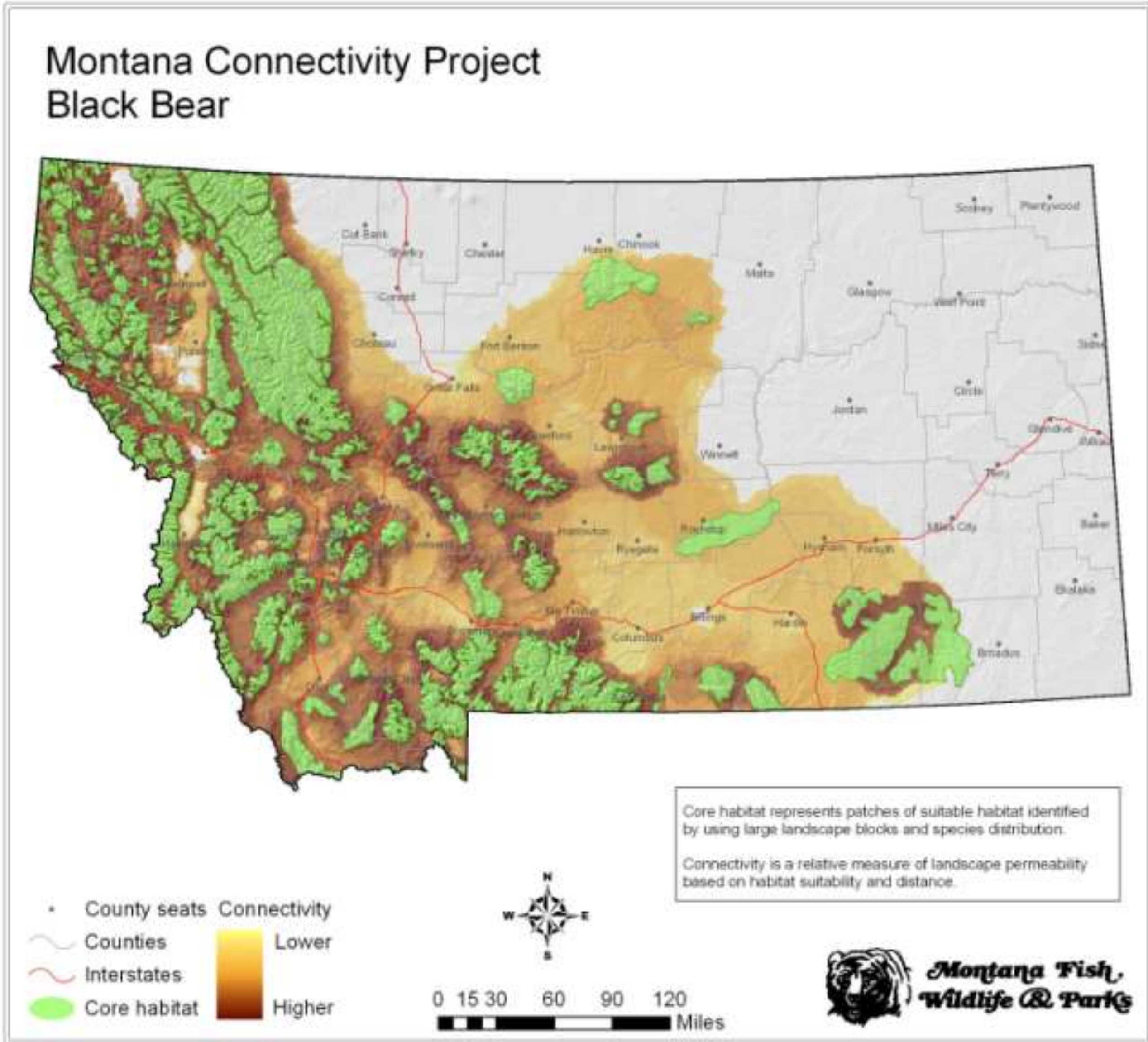


Figure 62. Black Bear core habitat and potential range/statewide landscape connectivity.

3.3.2.2. Canada Lynx (Lynx canadensis)

Group: Mammal

Ecosystem: Forest Specialist

Type of connectivity: Long-term, Range expansion/shift

Global/State Species of Concern Rank: G5/S3, Threatened

Confidence Rating: Core (Medium) Connectivity (Medium)

Figure 63. Canada Lynx Critical Habitat

Introduction

Canada Lynx are a resident terrestrial species considered a forest specialist that can be found across forest habitats in the western mountains of Montana. This species was selected as a focal species to represent high elevation forest and woodland habitats, and due to its status as a species of concern.

Supporting Information

- Critical Habitat - This layer is the USFWS critical habitat designations.

Patch Delineation

- 54 LILB Cores – All core patches of Forest LILB's overlapping the critical habitat areas were selected.

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
    - Local Scale
        - Pairwise comparisons of a source patch to all other patches within 25 km
            - Distance based upon visual estimation to connect core patches
        - 194 Local core patch pairs were identified
    - Regional Scale
        - Regions were created by combining all core patches with edges within 10 km of any adjacent patch
        - 4 Core patch regions were identified
        - Pairwise comparisons of a region to all other regions within 200 km
            - Distance based on connecting the Northern Continental Divide Ecosystem to Greater Yellowstone Ecosystem
        - 4 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
    - Generated a single corridor raster for each source layer pair within an analysis extent of 20 km beyond the greatest extent of the local patch pair and 40 km beyond the greatest extent of the regional patch pair
    - Selected the 20% lowest cost distance values for each pair for combination
    - Combined all individual pair corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single “least-cost” surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

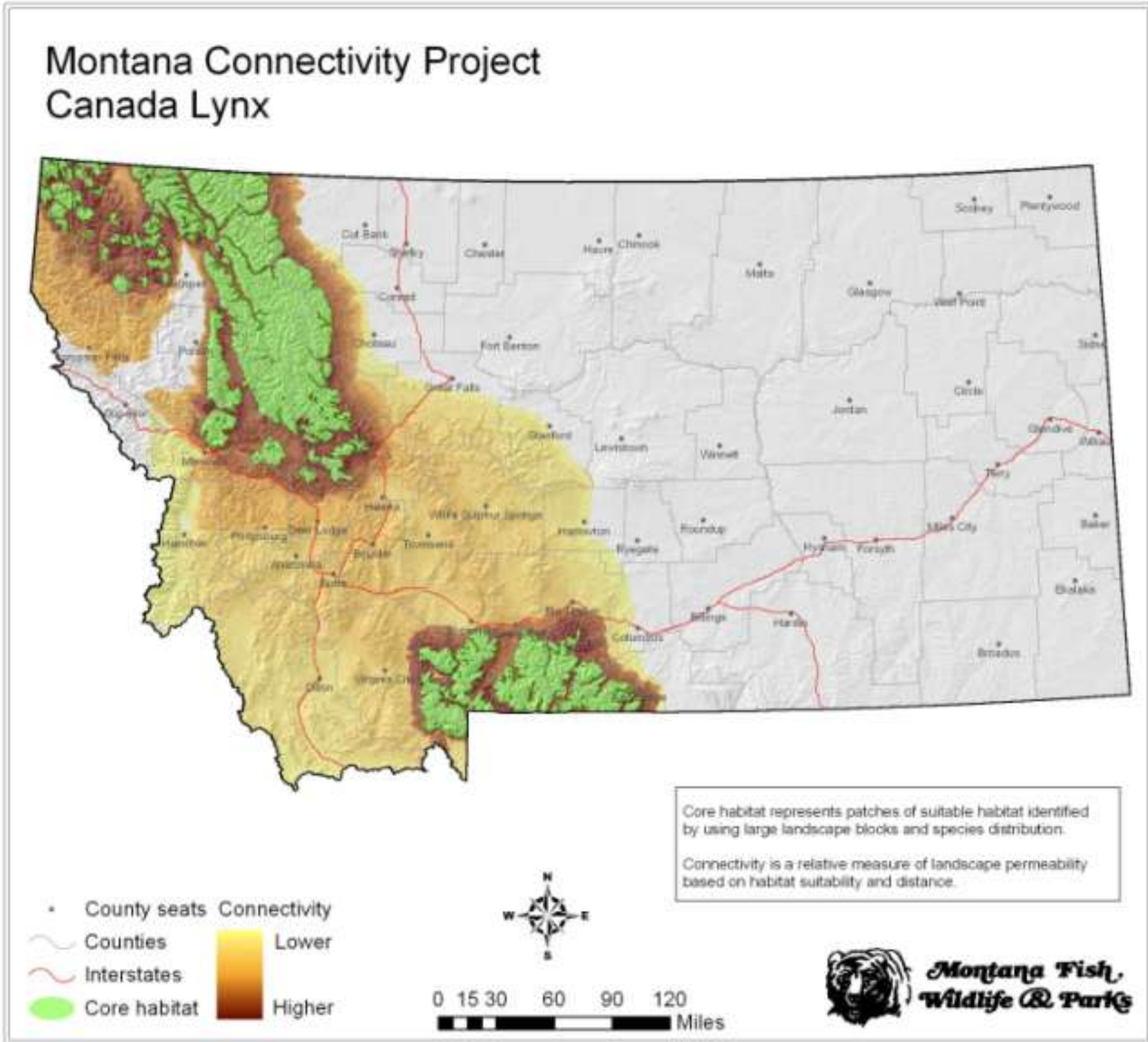


Figure 64. Canada Lynx core habitat and potential range/statewide landscape connectivity.

3.3.2.3. Elk (Cervus canadensis)

Group: Mammal

Ecosystem: Forest and Grassland Generalist

Type of connectivity: Seasonal

Economically Valued Species

Confidence Rating: Core (DNU) Connectivity (DNU)

Introduction

Figure 65. Elk Range

Elk are a resident terrestrial species considered a forest and grassland generalist that can be found across forest habitats as well as grassland and shrub steppe environments across Montana. This species was selected as a focal species to represent primarily forest and grassland habitats and due to its economic value to the state as a game species.

Supporting Information

- Species distribution - Expert knowledge layer maintained by MFWP biologists, available at: http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html

Patch Delineation

- 365 General LILB Cores – A core patches of General LILB's overlapping this species distribution were selected, as well as, all other core patches within Indian Reservations and National Parks.

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
  - Local Scale
    - Pairwise comparisons of a source patch to all other patches within 10 km
      - Distance based upon visual estimation to connect core patches
    - 796 Local core patch pairs were identified
  - Regional Scale
    - Regions were created by combining all core patches with edges within 5 km of any adjacent patch
    - 26 Core patch regions were identified

        - Pairwise comparisons of a region to all other regions within 150 km
            - Distance based on furthest distance to connect most isolated region of Sweetgrass hills to the Rocky Mountain Front
        - 106 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
    - Generated a single corridor raster for each source layer pair within an analysis extent of 10 km beyond the greatest extent of the patch pair and 20 km beyond the greatest extent of the regional patch pair
    - Selected the 20% lowest cost distance values for each pair for combination
    - Combined all individual pair corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

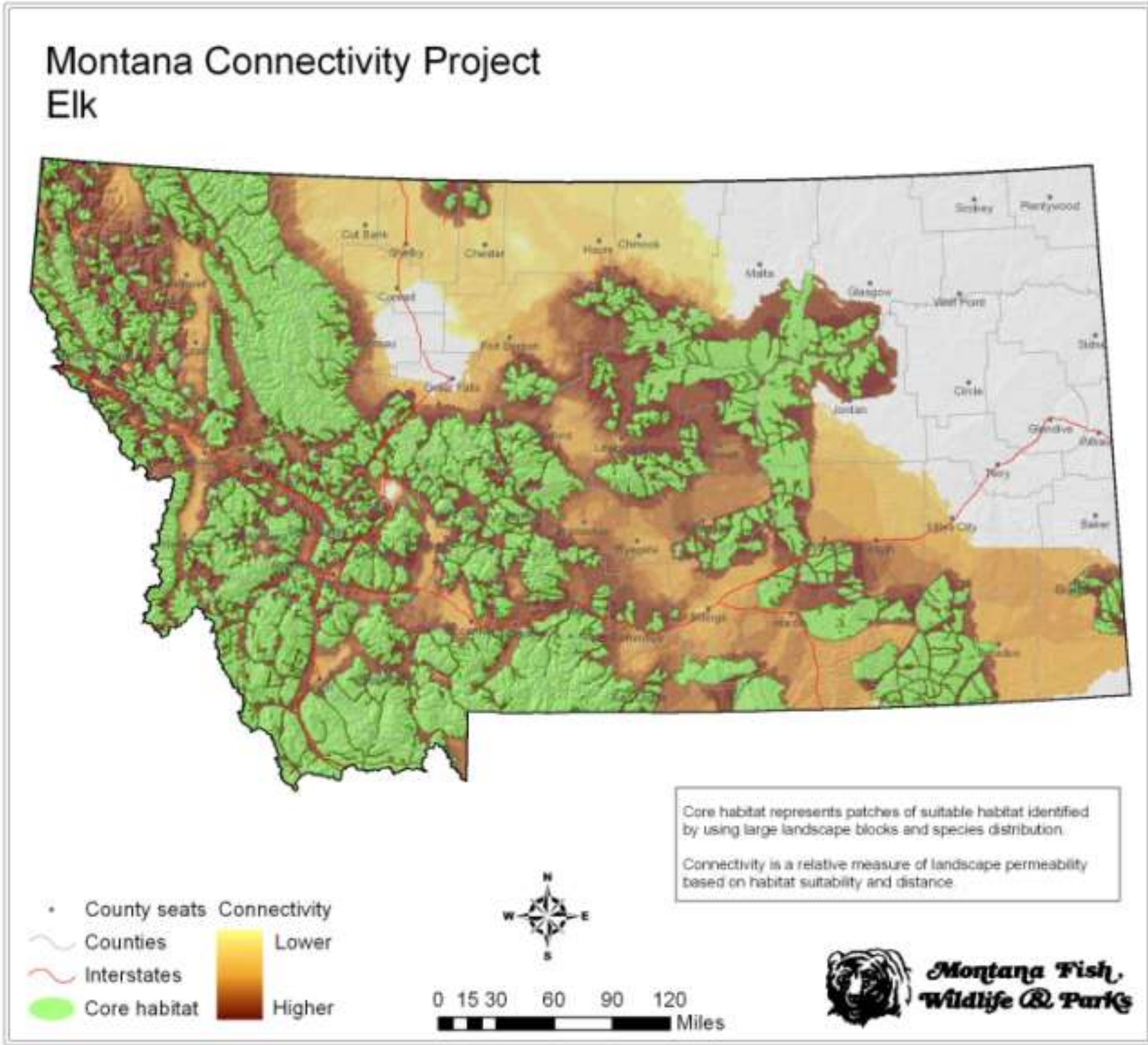


Figure 66. Elk core habitat and potential range/statewide landscape connectivity.

3.3.2.4. Grizzly Bear (Ursus arctos)

Group: Mammal

Ecosystem: Forest Generalist

Type of connectivity: Daily, Within season, Seasonal, Long-Term, Range shift/expansion

Global/State Species of Concern Rank: G4/S2S3, Threatened

Confidence Rating: Core (Medium) Connectivity (Medium)

Figure 67. Grizzly Bear Consistently Occupied Habitat

Introduction

Grizzly Bear are a resident terrestrial species considered a forest generalist that can be found across forest habitats in the western mountains of Montana. This species was selected as a focal species to represent forest and woodland habitats, and due to its status as a species of concern.

Supporting Information

- Consistently Occupied Habitat (COH) - This layer is a representation of distribution that is based upon the USFWS critical habitat designations and federal recovery areas of the Northern Continental Divide Ecosystem (NCDE) and Greater Yellowstone Ecosystem (GYE). These areas were expanded to include areas of consistently occupied habitat as identified by bear biologists across Montana.

Patch Delineation

- 72 LILB Cores – All core patches of Forest LILB's overlapping the COH were selected.

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
  - Local Scale
    - Pairwise comparisons of a source patch to all other patches within 25 km
      - Distance based upon visual estimation to connect core patches
    - 258 Local core patch pairs were identified
  - Regional Scale

        - Regions were created by combining all core patches with edges within 10 km of any adjacent patch
        - 6 Core patch regions were identified
        - Pairwise comparisons of a region to all other regions within 200 km
            - Distance based on connecting the NCDE to GYE
        - 8 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
    - Generated a single corridor raster for each source layer pair within an analysis extent of 20 km beyond the greatest extent of the local patch pair and 40 km beyond the greatest extent of the regional patch pair
    - Selected the 20% lowest cost distance values for each pair for combination
    - Combined all individual pair corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

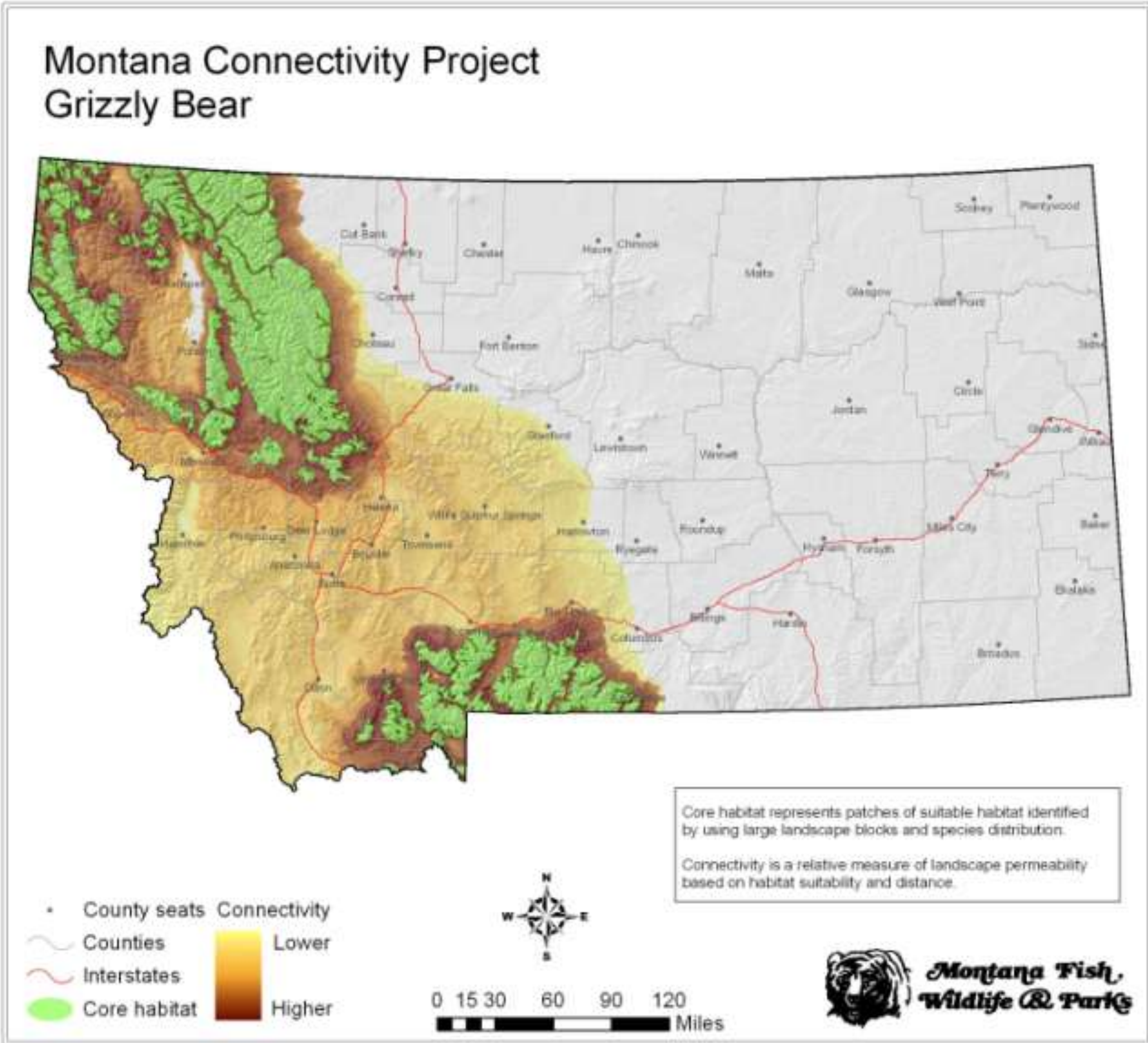


Figure 68. Grizzly Bear core habitat and potential range/statewide landscape connectivity.

3.3.2.5. Moose (Alces americanus)

Group: Mammal

Ecosystem: Forest Specialist

Type of connectivity: Seasonal, Range shift/expansion

Economically Valued Species

Confidence Rating: Core (Low) Connectivity (Low)

Figure 69. Moose Range

Introduction

Moose are a resident terrestrial species considered a forest specialist that can be found across forest habitats and wetland/riparian habitats, primarily in the western mountains of Montana. This species was selected as a focal species to represent forest and woodland habitats and due to its economic value to the state as a game species.

Supporting Information

- Species distribution - Expert knowledge layer maintained by MFWP biologists, available at: http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html

Patch Delineation

- 166 LILB Cores – All core patches of Forest LILB's overlapping this species distribution were selected, as well as, all other forest core patches within Indian Reservations and National Parks. Also included areas of this species distribution in the Ruby Mountains, Sweetgrass Hills and areas of winter range near Dillon.

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
    - Local Scale
        - Pairwise comparisons of a source patch to all other patches within 25 km
            - Distance based upon visual estimation to connect core patches
        - 571 Local core patch pairs were identified
    - Regional Scale
        - Regions were created by combining all core patches with edges within 15 km of any adjacent patch

        - 13 Core patch regions were identified
        - Pairwise comparisons of a region to all other regions within 150 km
            - Distance based on furthest distance to connect most isolated region, the Sweetgrass Hills
        - 34 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
    - Generated a single corridor raster for each source layer pair within an analysis extent of 10 km beyond the greatest extent of the patch pair and 20 km beyond the greatest extent of the regional patch pair
    - Selected the 20% lowest cost distance values for each pair for combination
    - Combined all individual pair corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

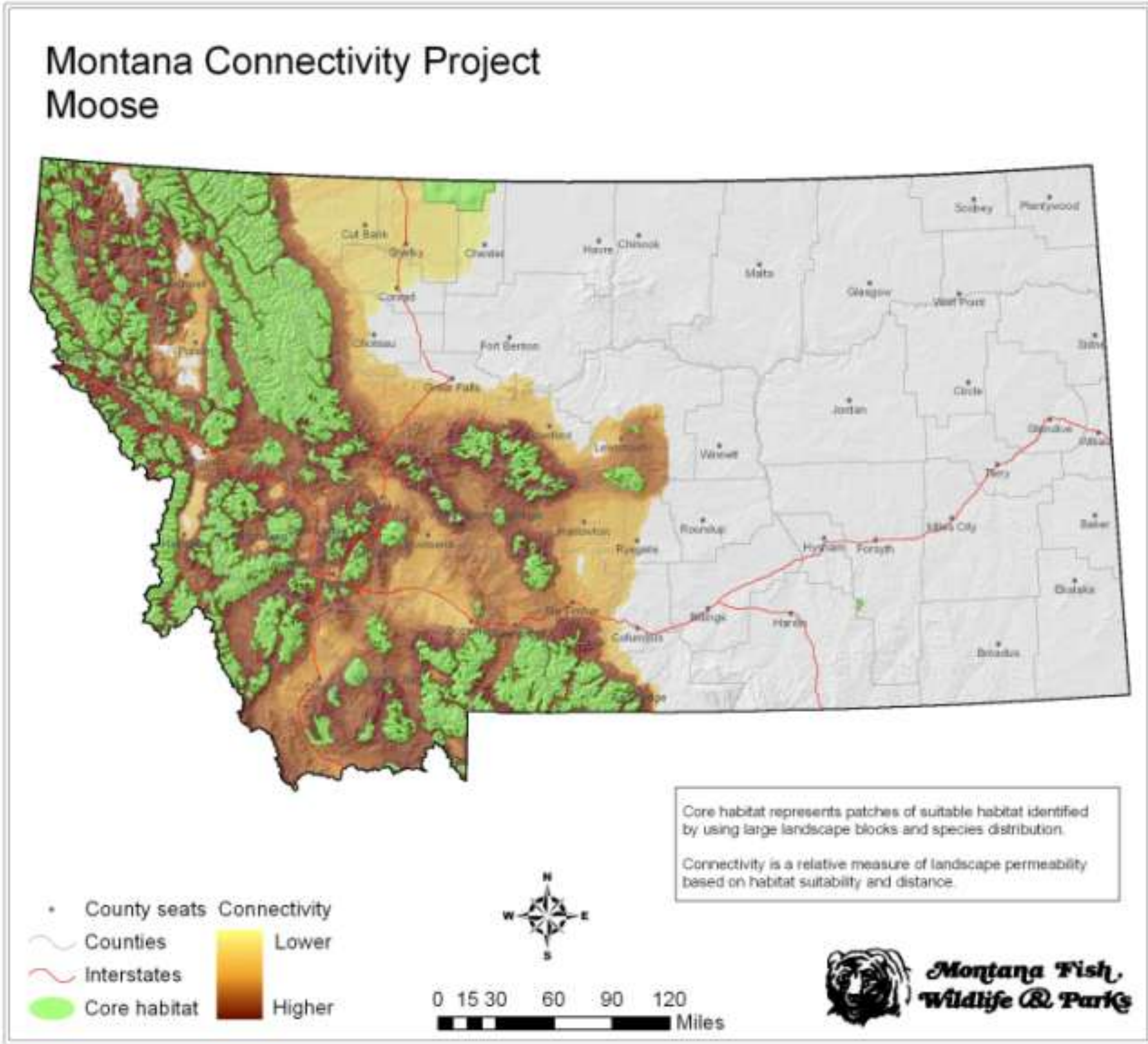


Figure 70. Moose core habitat and potential range/statewide landscape connectivity.

3.3.2.6. Mountain Lion (Puma concolor)

Group: Mammal

Ecosystem: Forest Generalist

Type of connectivity: Seasonal, Long term

Economically Valued Species

Confidence Rating: Core (Medium) Connectivity (Low)

Figure 71. Mountain Lion Range

Introduction

Mountain Lion are a resident terrestrial species considered a forest generalist that can be found across forest habitats as well as grassland and shrub steppe environments with supporting habitat characteristics such as sufficient topography. This species was selected as a focal species to represent primarily forest and woodland habitats and due to its economic value to the state as a game species.

Supporting Information

- Species distribution - Expert knowledge layer maintained by MFWP biologists, available at: http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html

Patch Delineation

- 347 LILB Cores – Within western Montana, all core patches of Forest LILB's overlapping this species distribution were selected, as well as, all other forest core patches within Indian Reservations and National Parks. In the prairie habitats of eastern Montana, all General LILB cores overlapping this species distribution were selected.

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
    - Local Scale
        - Pairwise comparisons of a source patch to all other patches within 25 km
            - Distance based upon visual estimation to connect core patches
        - 1607 Local core patch pairs were identified
    - Regional Scale

- Regions were created by combining all core patches with edges within 15 km of any adjacent patch
- 9 Core patch regions were identified
- Pairwise comparisons of a region to all other regions within 100 km
  - Distance based on furthest distance to connect most isolated region
- 20 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
  - Generated a single corridor raster for each source layer pair within an analysis extent of 10 km beyond the greatest extent of the patch pair and 20 km beyond the greatest extent of the regional patch pair
  - Selected the 20% lowest cost distance values for each pair for combination
  - Combined all individual pair corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

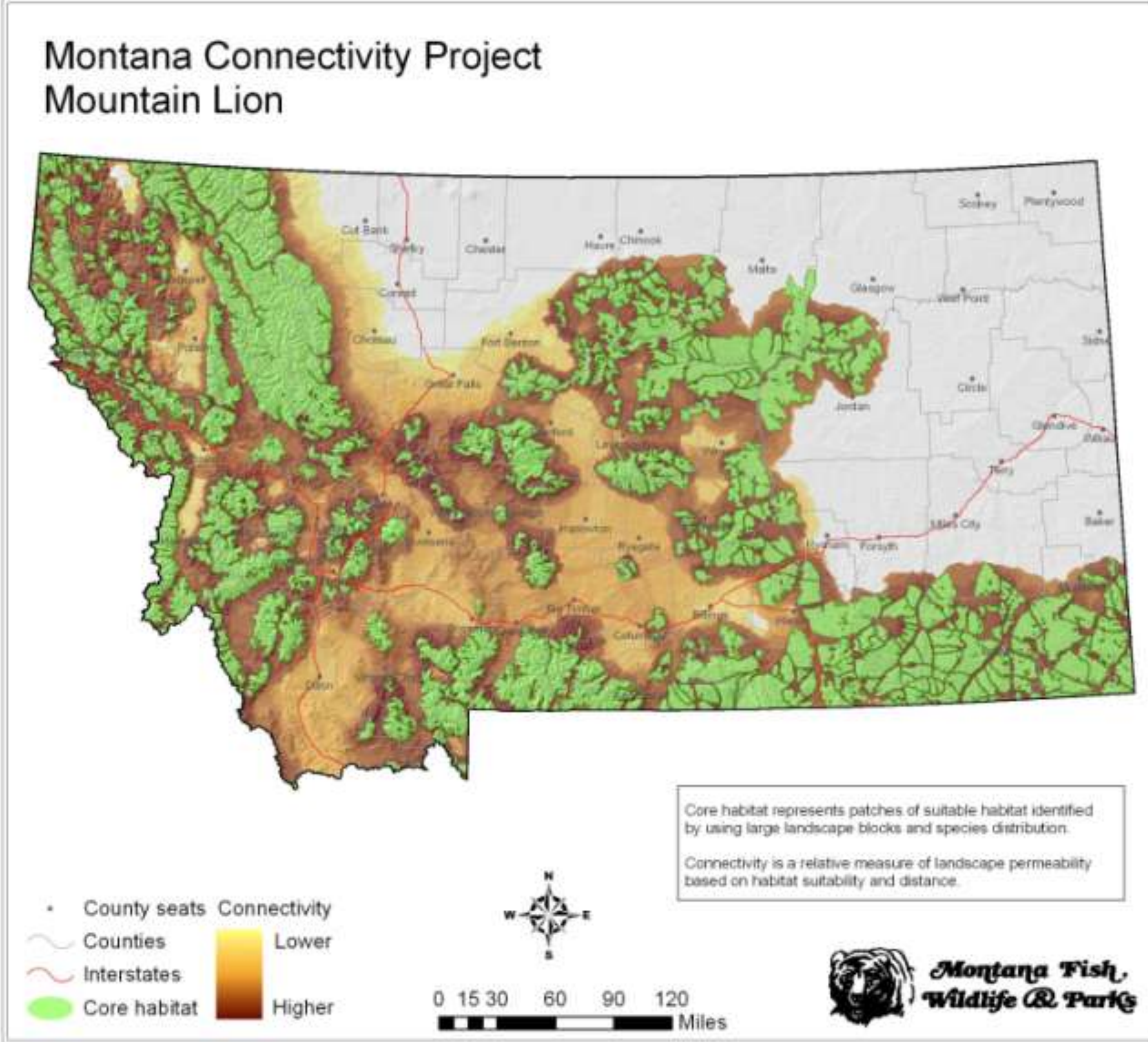


Figure 72. Mountain Lion core habitat and potential range/statewide landscape connectivity.

3.3.2.7. Mule Deer (Odocoileus hemionus)

Group: Mammal

Ecosystem: Forest/Shrub/Grassland - Generalist

Type of connectivity: Seasonal

Economically Valued Species

Confidence Rating: Core (DNU) Connectivity (DNU)

Figure 73. Mule Deer Range

Introduction

Mule deer are a resident terrestrial species considered a generalist that can be found across forest, grassland, and shrub steppe environments across the whole state. This species was selected as a focal species to represent primarily grass/shrub habitats and due to its economic value to the state as a game species.

Supporting Information

- Species distribution - Expert knowledge layer maintained by MFWP biologists, available at: http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html

Patch Delineation

- 780 General LILB Cores – All core patches of LILB's overlapping this species distribution were selected, as well as all other core patches within Indian Reservations and National Parks.

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized General Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
  - Local Scale
    - Pairwise comparisons of a source patch to all other patches within 10 km
      - Distance based upon visual estimation to connect core patches
    - 2011 Local core patch pairs were identified
  - Regional Scale
    - Regions were created by combining all core patches with edges within 5 km of any adjacent patch
    - 61 Core patch regions were identified

- Pairwise comparisons of a region to all other regions within 70 km
  - Distance based on furthest distance to connect most isolated region
- 240 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
  - Generated a single corridor raster for each source layer pair within an analysis extent of 10 km beyond the greatest extent of the patch pair and 20 km beyond the greatest extent of the regional patch pair
  - Selected the 20% lowest cost distance values for each pair for combination
  - Combined all individual pair corridor rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single "least-cost" surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as core habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

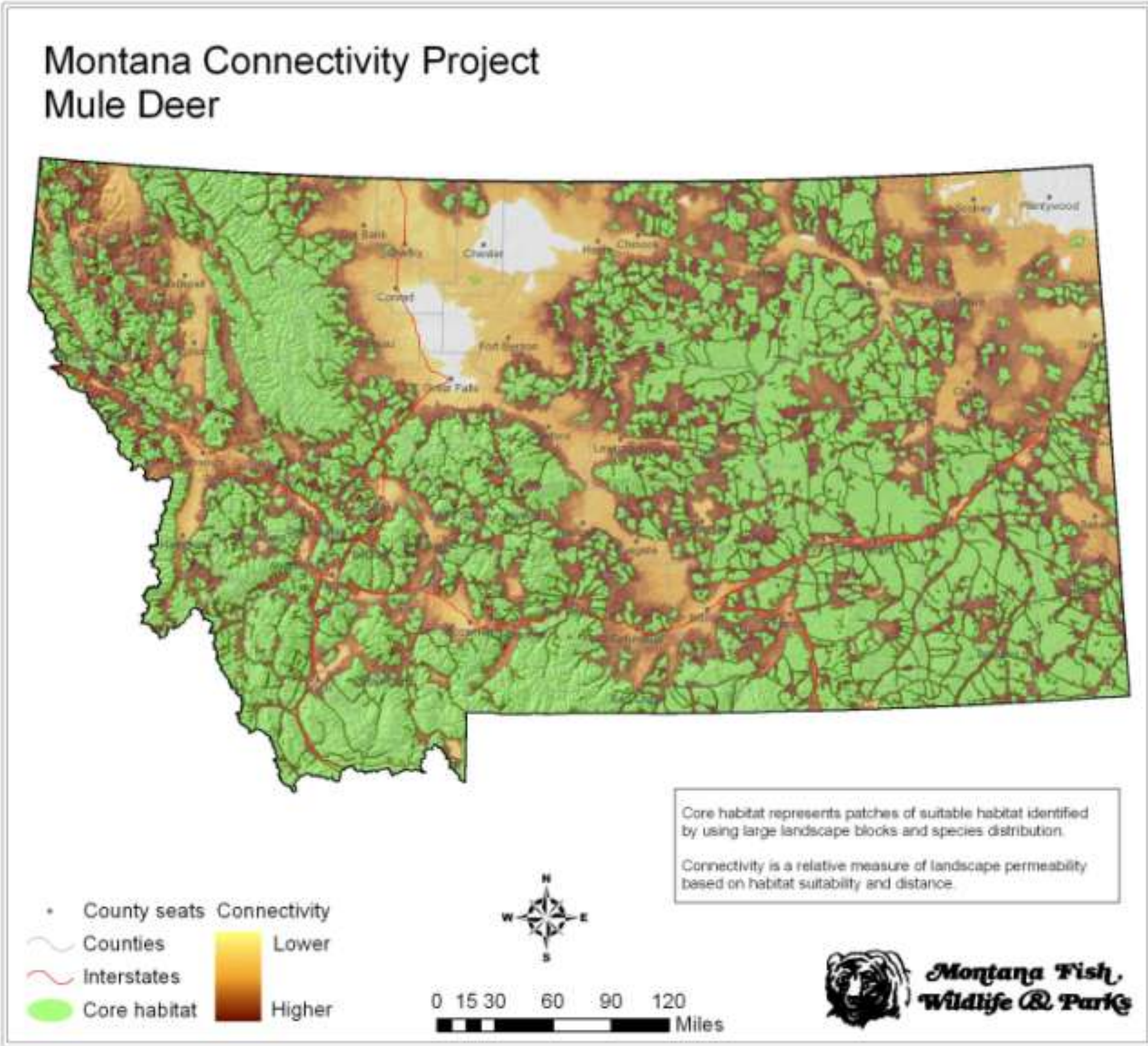


Figure 74. Mule Deer core habitat and potential range/statewide landscape connectivity.

3.3.2.8. **Pronghorn** (Antilocapra americanus)

Group: Mammal

Ecosystem: Grassland/Shrub

Type of connectivity: Daily, Within season, Seasonal

Economically Valued Species

Confidence Rating: Core (Medium) Connectivity (Medium)

Figure 75. Pronghorn Range

Introduction

Pronghorn antelope are a resident terrestrial species commonly associated with sagebrush grassland habitats. This species was selected as a focal species to represent grassland and shrub steppe environments, and due to its economic value to the state as a game species.

Supporting Information

- Species distribution - Expert knowledge layer maintained by MFWP biologists, available at: http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html

Patch Delineation

- 510 Grass LILB Cores – All core patches of LILB's overlapping this species distribution were selected, as well as all other grass cores within Indian Reservations, except those in the Flathead area

Connectivity Delineation

The connectivity analysis was conducted using the Create Corridor Raster tool developed by the Craighead Institute. The Create Corridor Raster was run with the following parameters:

- Utilized Grassland Species cost layer to generate cost-distance surface
- Generated a file to represent all patch pair comparisons at two scales
    - Local Scale
        - Pairwise comparisons of a source patch to all other patches within 10 km
            - Distance based upon visual estimation to connect core patches
        - 949 Local core patch pairs were identified
    - Regional Scale
        - Regions were created by combining all core patches with edges within 5 km of any adjacent patch
        - 113 Core patch regions were identified
        - Pairwise comparisons of a region to all other regions within 60 km

            - Distance based on those between grassland cores on the Rocky Mountain Front
        - 384 Regional pairs were identified

- The following steps were conducted at both the local and regional scale
    - Generated a single corridor raster for each source layer pair within an analysis extent of 10 km beyond the greatest extent of the patch pair and 20 km beyond the greatest extent of the regional patch pair
    - Selected the 20% lowest cost distance values for each pair for combination
    - Combined all individual pair corridor rasters into a single “least-cost” surface by calculating the cell-based minimum for each cell
- Combined the Local and Regional scale rasters into a single “least-cost” surface by calculating the cell-based minimum for each cell
- Sliced the combined least-cost corridor raster into 100 1% slices for display of the relative values

This process was undertaken using all identified patches within the extent of the state. Raster slice maps were converted to vector format.

Assumptions:

- It was assumed that LILB areas identified as grassland/shrub/steppe habitat effectively represent source and destination core habitat patches for this species.
- It was assumed that the response of this species to the habitat factors identified in the LILB methods represent the true cost of those factors to this species.

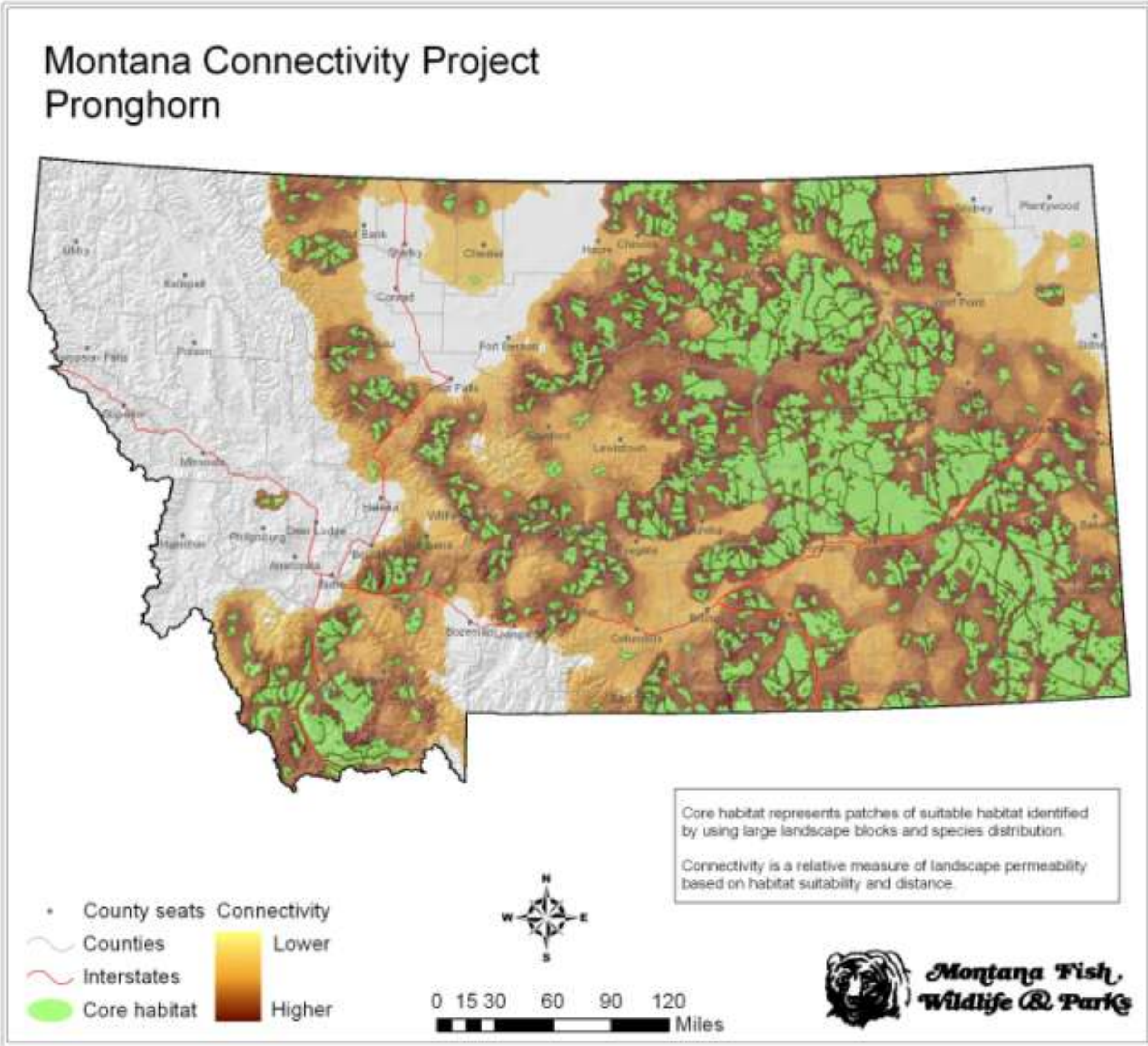


Figure 76. Pronghorn core habitat and potential range/statewide landscape connectivity.

3.3.3. Large Landscape Blocks Ecotype Models

General Information

After a limited review of the LLB species models, models were run for ecotypes independent of species level input. By using the word ecotype we are indicating general ecological groupings based upon primary habitat associations. With input gained from the species reviews the ecotype based models were adjusted to include a forest generalist category, and revise the cost surfaces needed for each group. The resulting groups included: All General, Alpine, Grass/Shrub, Forest Generalist and Forest Specialist. The ecological system associations for the ecotype models are shown in table 7. Cost layer values were adjusted as shown in Appendix J.

The core habitat patches for the ecotype models were generated the same way as described for the LLB's with the exception of the forest generalist type. For the original LLB models each ecological system that was associated with a particular ecotype, was considered "native". Thus, only those ecological systems with that association were carried forward to calculate contiguous areas consisting of 90% "native". However, for the forest generalist category, pixels had to have at least 40% of the surrounding landscape consisting of forest cover before being assessed if they were native. If the pixel met both characteristics it was flagged "native" and moved to the next step to consider if 90% of the area was native for the formation of a block.

These layers are still being reviewed as of the time this document. Limited feedback has shown that this technique shows promise and has fewer assumptions and more potential utility to address species needs on a structural rather than functional basis.

The following sections have no supporting text beyond that provided here. A cost model and core/connectivity model image is provided for each ecotype.

3.3.3.1. All General

Example Species: Mule Deer, Elk

Confidence Rating: Core (NE) Connectivity (NE)

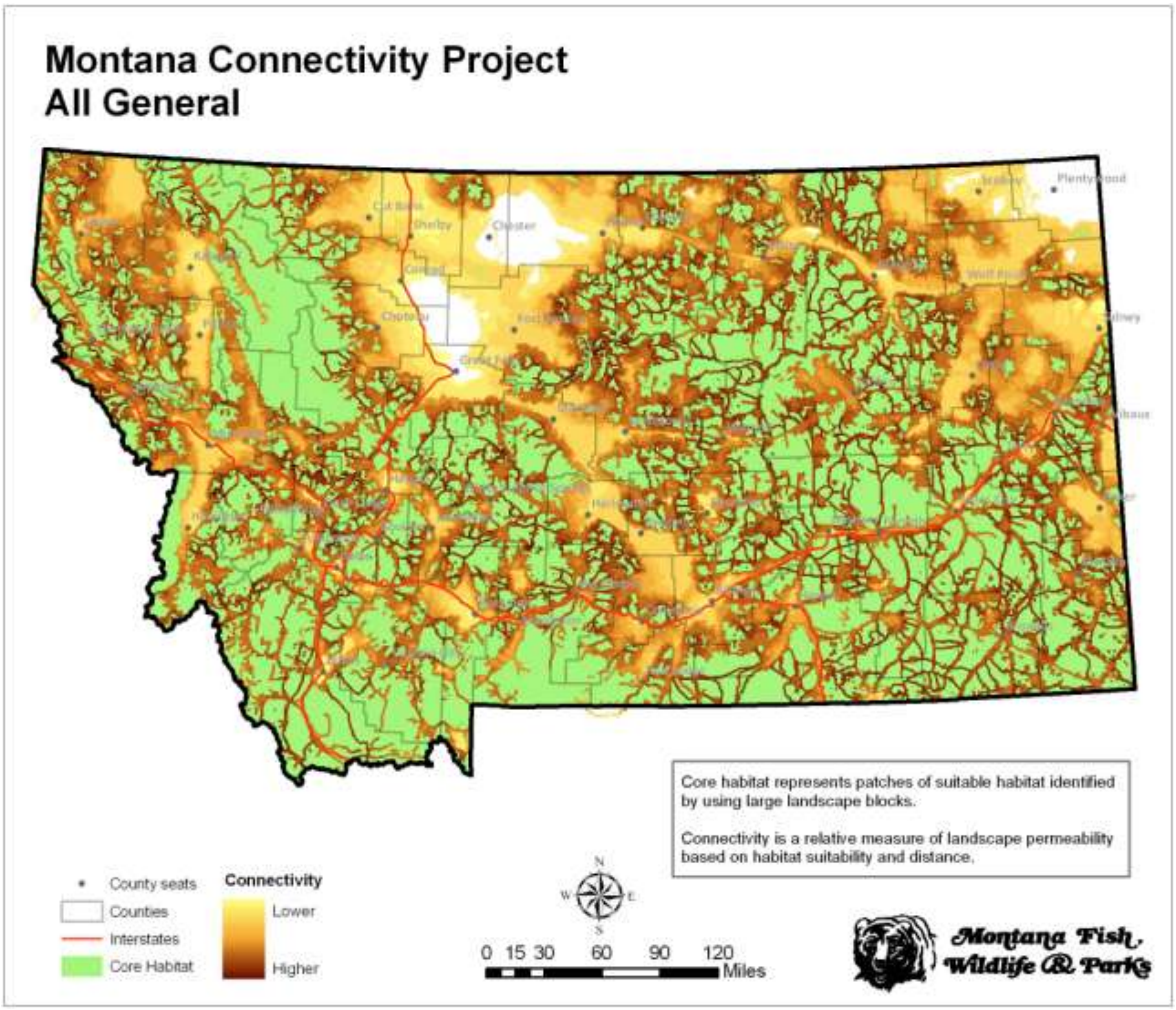


Figure 77. All General core habitat and potential range/statewide landscape connectivity.

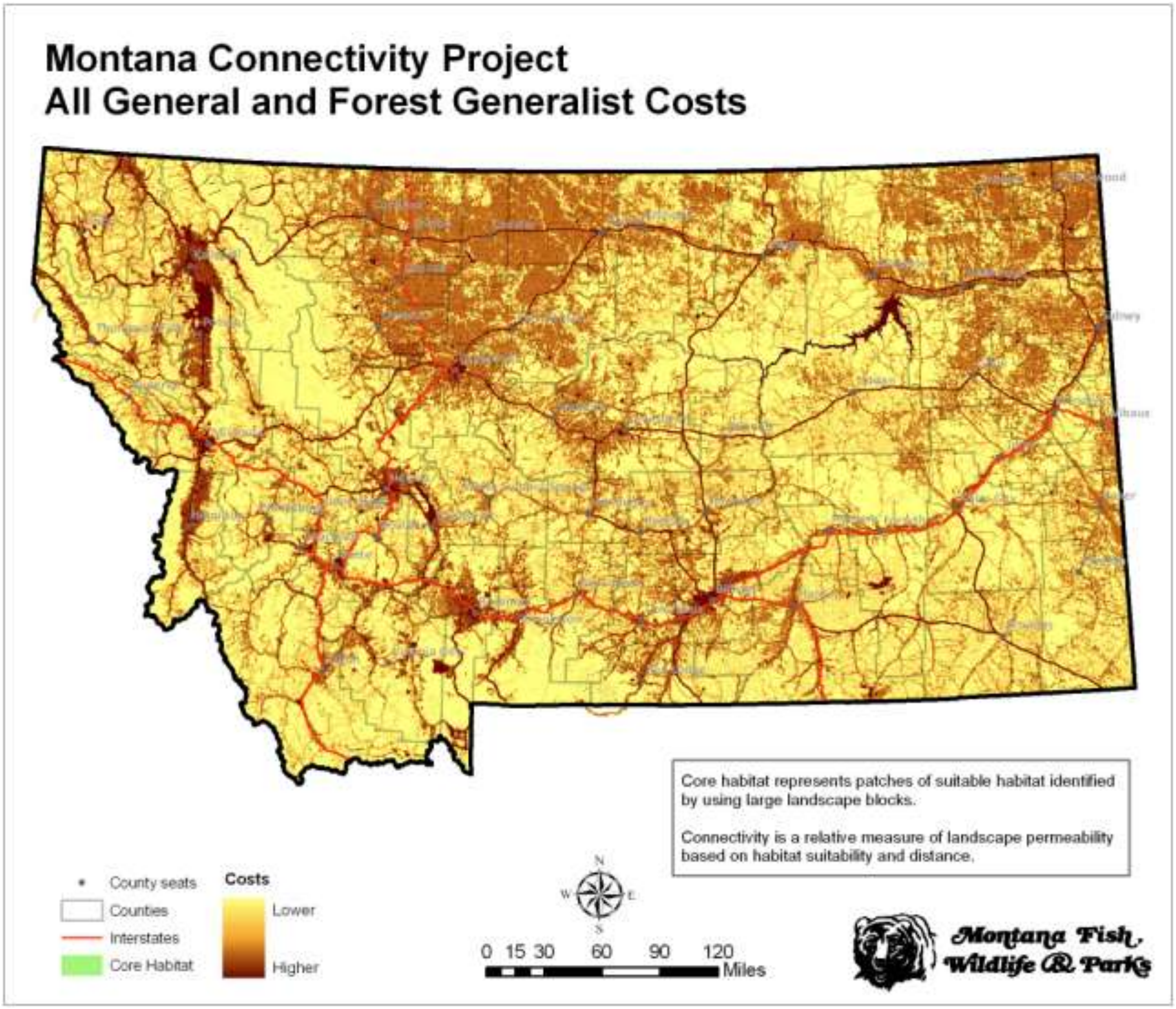


Figure 78. All General and Forest Generalist Costs for landscape connectivity.

3.3.3.2. Alpine

Example Species: Black Rosy-Finch, Wolverine

Confidence Rating: Core (NE) Connectivity (NE)

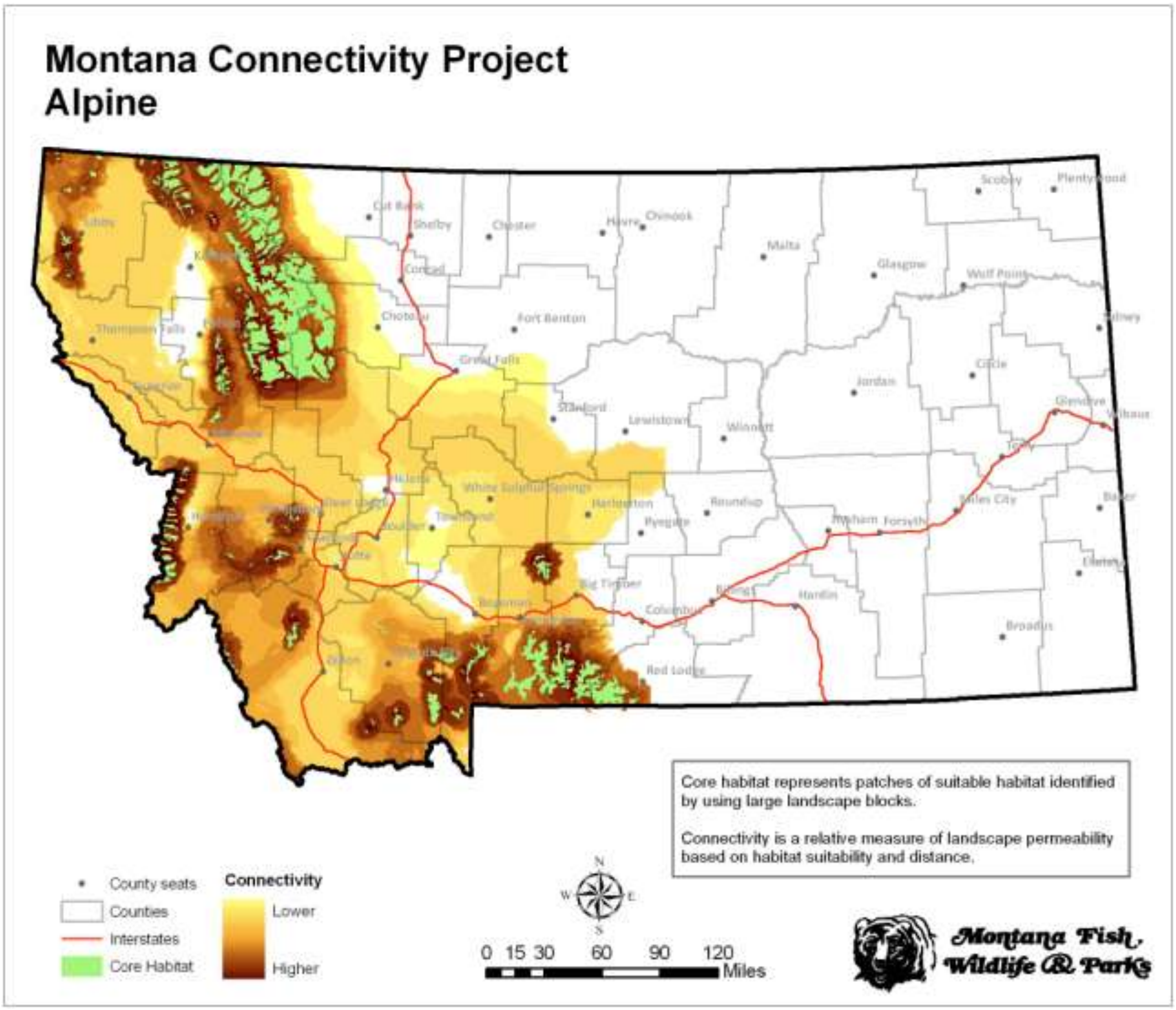


Figure 79. Alpine core habitat and potential range/statewide landscape connectivity.

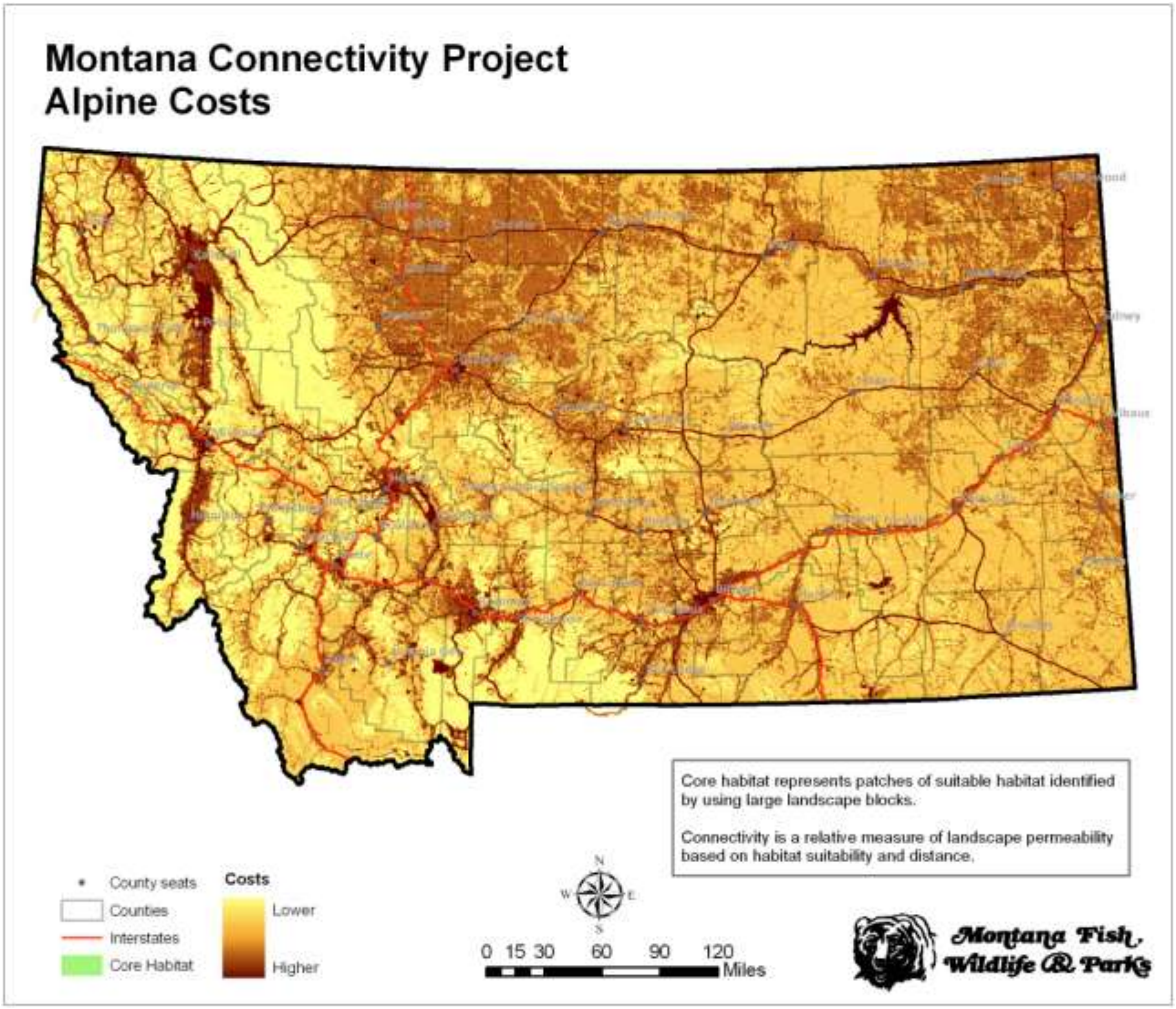


Figure 80. Alpine Costs for landscape connectivity.

3.3.3.3. Grass/Shrub

Example Species: Black-tailed Prairie Dog, Pronghorn Antelope, Swift Fox, Baird's Sparrow, Ferruginous Hawk, Long-billed Curlew, Mountain Plover

Confidence Rating: Core (NE) Connectivity (NE)

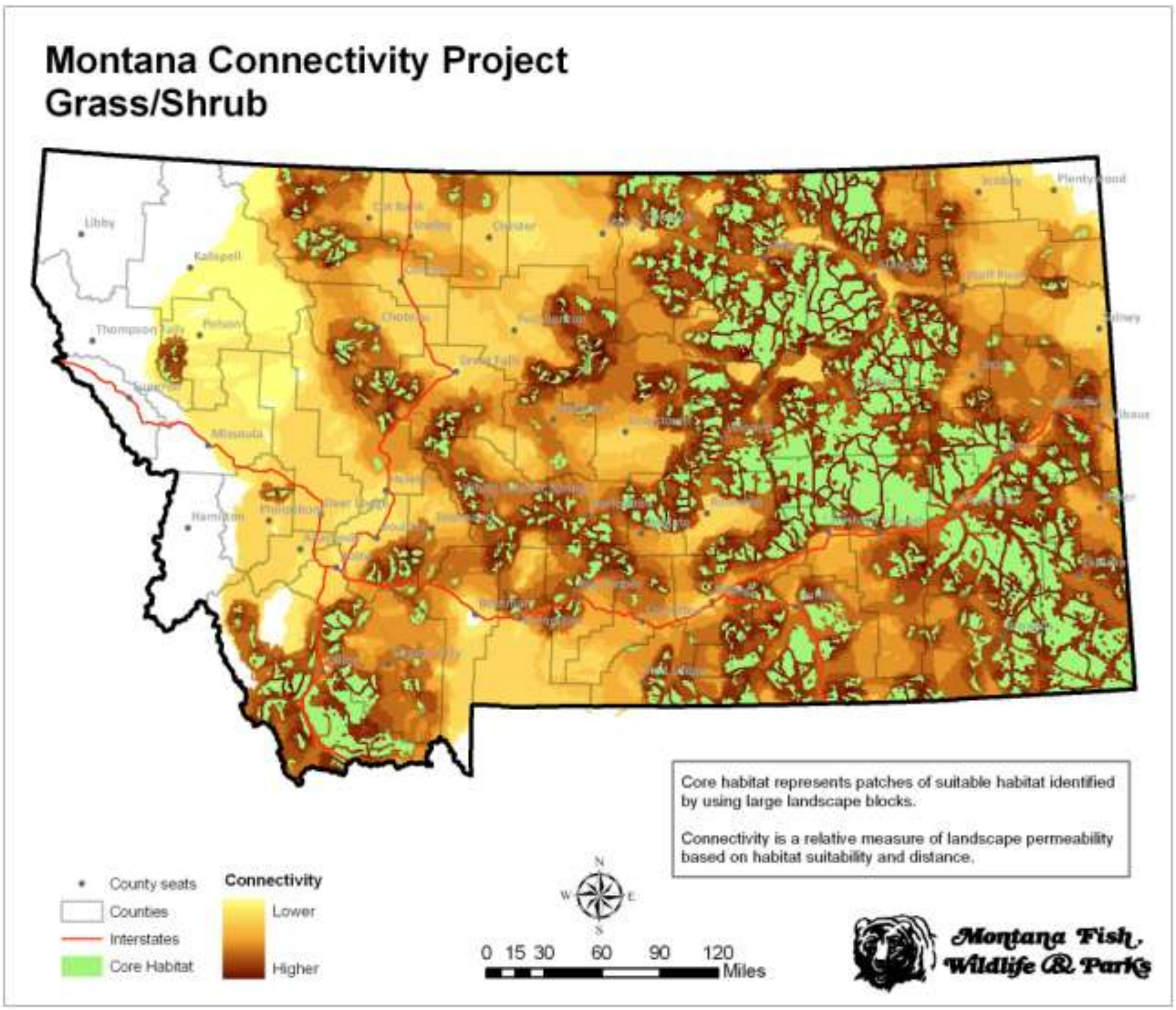


Figure 81. Grass/Shrub core habitat and potential range/statewide landscape connectivity.

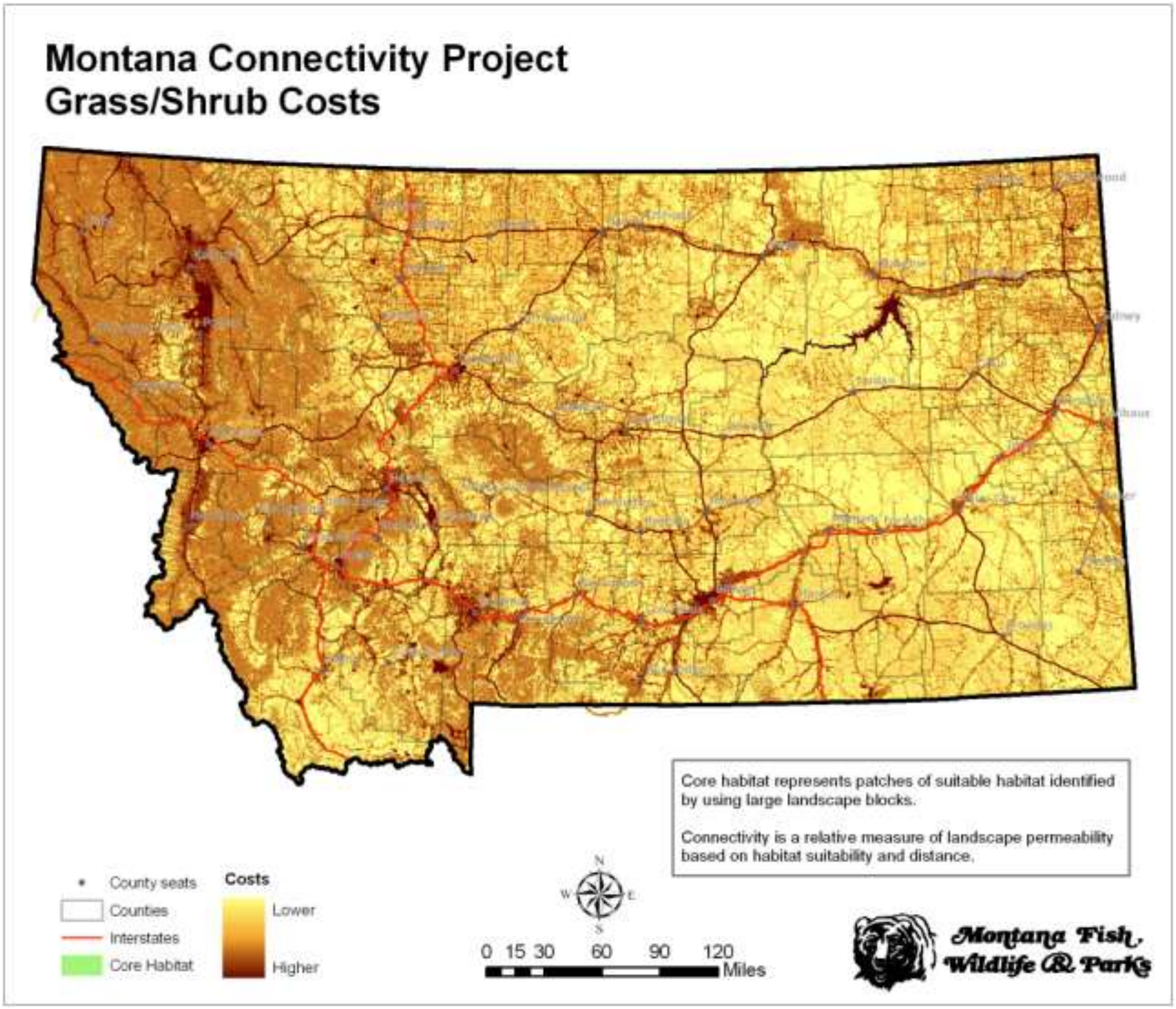


Figure 82. Grass/Shrub costs for modeling landscape connectivity.

3.3.3.4. Forest Generalist

Example Species: Black Bear, Elk, Grizzly Bear, Mountain Lion

Confidence Rating: Core (NE) Connectivity (NE)

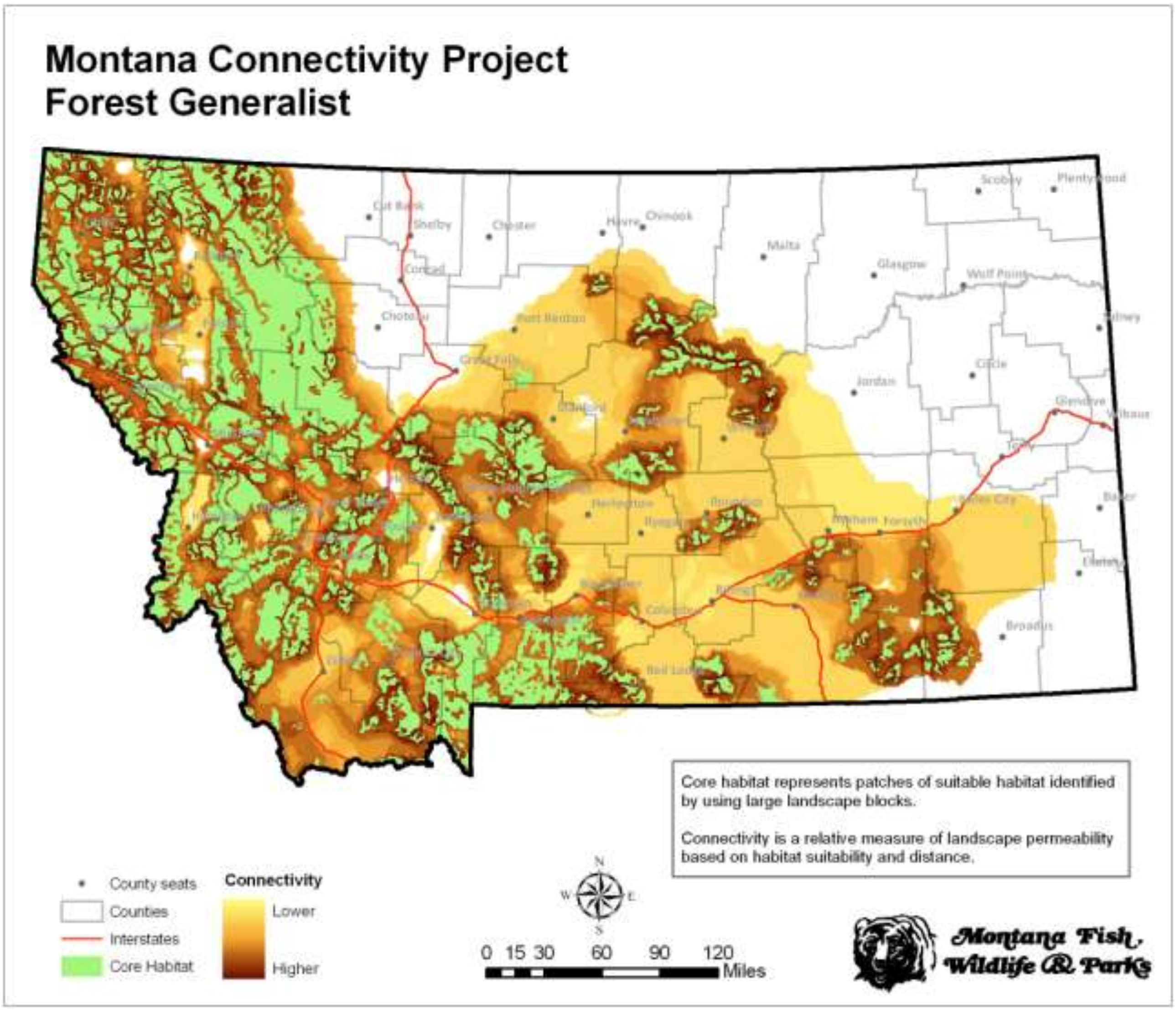


Figure 83. Forest Generalist core habitat and potential range/statewide landscape connectivity.

3.3.3.5. Forest Specialist

Example Species: Lynx, Moose, Cassin's Finch, Clark's Nutcracker, Wolverine

Confidence Rating: Core (NE) Connectivity (NE)

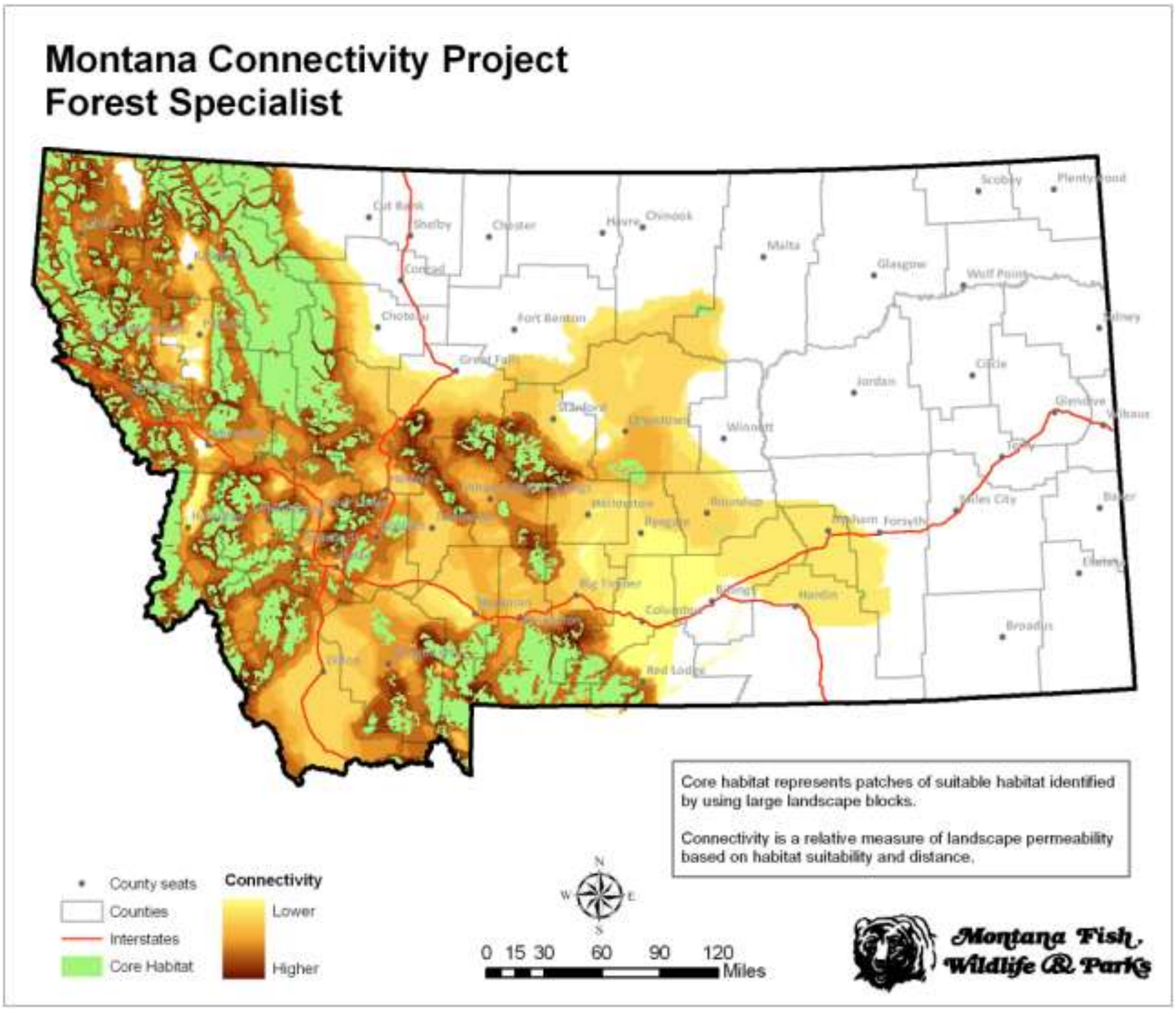


Figure 84. Forest Specialist core habitat and potential range/statewide landscape connectivity.

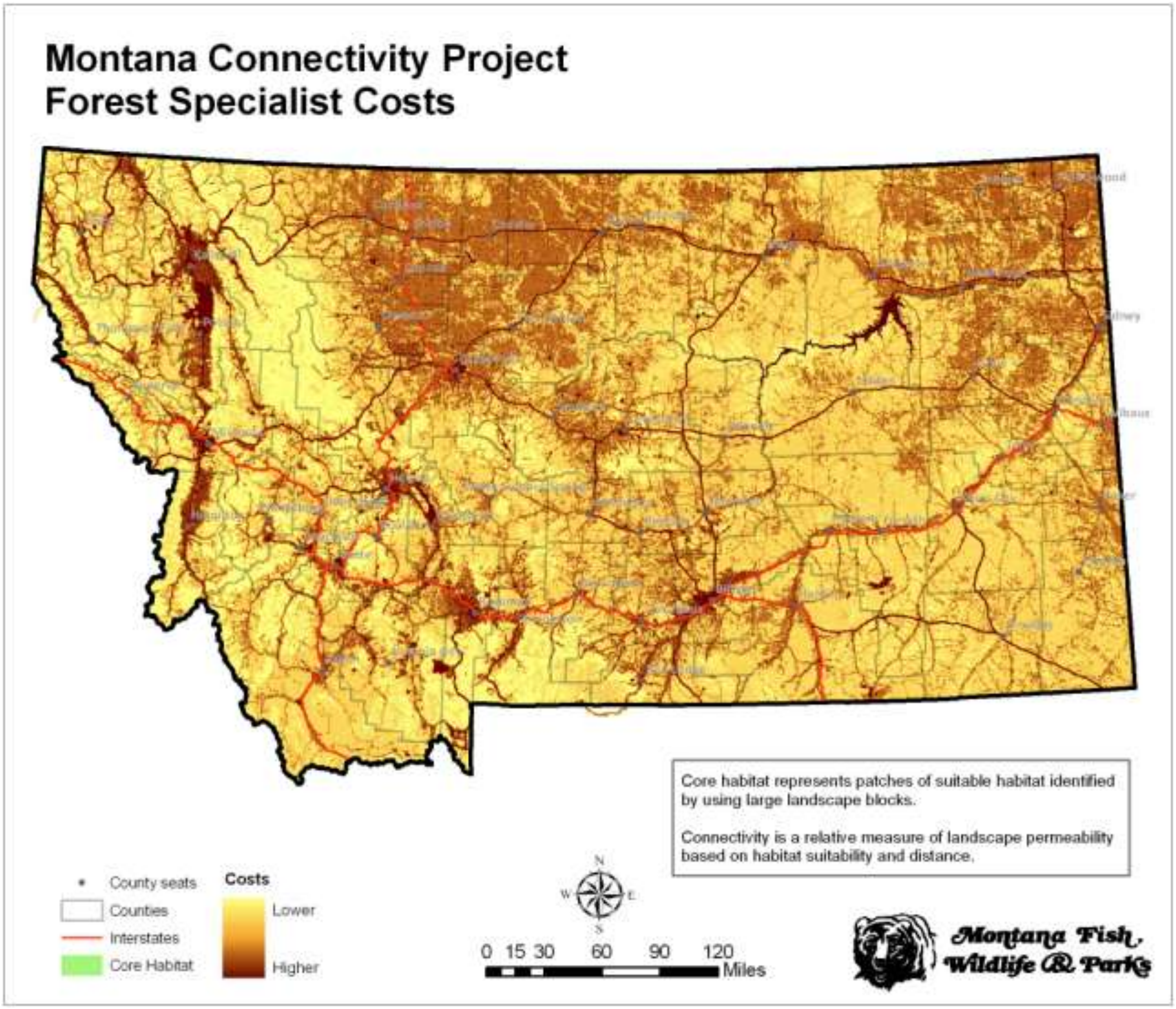


Figure 85. Forest Specialist Costs for landscape connectivity.

3.3.4. Suggestions for Future Improvements

For the large landscape block species and ecotypes, these reviews were relatively incomplete. The techniques were developed late in the connectivity modeling process and have not been fully vetted against expert knowledge. Many other sources of data and expert knowledge exist that should brought to the review of this technique.

The LILB connectivity technique is a general start to the process of looking at structural connectivity for an ecosystem level approach for all species. The technique is most applicable for broad scale movements or connectivity covering a broad temporal range. As described, the Mule Deer connectivity model uses all general cores identified, and if the parameters used to create cores as well as local and regional connections are reasonable this technique shows promise for further assessment.

4. DISCUSSION

4.1. Modeling Results Discussion

Interpreting Connectivity maps

Connectivity maps are the result of a modeling exercise that illustrate the lowest cumulative cost-distance associated with an individual of the focal species being modeled moving between/among patches of core habitat. Output of the connectivity modeling exercise is a raster data set that provides a continuous representation of the lowest cumulative cost-distance values across the landscape. This raw output, however, is difficult to interpret. To aid in interpretation, the raw data are processed one more time to slice up the continuously represented data into 20 discrete bands. Each band represents 5 percent of the values that make up the map. Typically the pattern is that bands radiate out from patches of core habitat. Bands closest to cores typically represent lower cost-distance values, whereas bands further away from cores typically represent higher cost-distance values. In other words, bands with the lower cost-distance values can be viewed as being easier to move through as a function of distance and landscape characteristics. These areas represent high landscape permeability for the focal species. The inverse is true for areas with higher cost-distance values.

It is *critical* to note that these bands do not represent a relative ranking of use or importance in terms of connectivity for the focal species. Just because a band or group of bands represents low cost-distance values does not mean it is used most often or is the most important for one or more of the types of connectivity this analysis is meant to illustrate. The inverse of this is also true. In fact, areas in the outer bands of the connectivity map may be the most important, as they may facilitate that once in a century dispersal event that connects two isolated populations.

4.2 Future Integration

Montana Fish, Wildlife and Parks completed the individual species layers and species guild in July 2011 following extensive research, development and expert review. The first 3 objectives of creating a statewide assessment for 25 species and 4 species guilds was accomplished. All species required developing new models/products because of the scattered geographic nature of existing data.

The remainder of the grant's objectives focus on integration of the connectivity products into the operations of local, state and federal government and private and public entities through a public available mapping system. The first step in the integration phase was to explore creating a visually simplified product of the nearly 30 individual layers into a useful interpretation of connectivity, similar to what has been done with other data types in the Crucial Areas Planning System (CAPS). The benefits of this approach is that it reduces visual confusion and interpretation when comparing individual species; broadens and expands number of species and habitat considered during project review; and allows data to be compared with other data layers easily. With avian guilds and individual species and terrestrial large and small mammals, the need to aggregate at some level became apparent. The approaches that will be looked at include:

- Focal species as umbrella species – can we use this concept further to use one species to serve as an umbrella for others?
- Species Composites – can we aggregate species at either a species group level or ecosystem level?
- Coarse connectivity based on the Large Intact Landscape Blocks – can we use the connectivity developed using the Large Intact Landscape Blocks (mule deer used all cores) as a surrogate for a group of focal species?

In order to address what approach should be taken in creating a composite of connectivity, important to understand how our constituents would use the products created. The questions of what do you need and how will you use the products will be evaluated and will be used to influence the final product development. The evaluation will include addressing the issue of scale (coarse scale/fine scale) and determining what is the appropriate scale to use Montana Connectivity data and how using finer scale existing connectivity products would be incorporated and/or provide guidance for their use.

The final objective that will need to be addressed is how/if connectivity layers will be prioritized based on the guidance provided by the Western Governors' Association's Wildlife Council's White

Paper, *"Western Regional Wildlife Decision Support System: Definitions and guidance for State Systems"* (WGA 2011). Questions to explore will include:

- What do we use to categorize locations on the landscape most important for maintaining/improving population connectivity?
    - More use by more species = more value?
    - More permeability, higher value? More resistance, higher value?

These, and other questions, will be explored over the course of the remainder of 2011 and the report to the WCS will be updated at that time. The integration of the final products into CAPS will occur prior to the prioritization process.

4.3. Improvements to Connectivity Modeling Process

1. Edge effects
    a. We modeled areas solely within the boundaries of Montana. Improvements to data layer availability and cross border modeling will facilitate the identification of edge effects.
2. Improved parameterization in the Create habitat patch module of CorridorDesigner
    a. Sufficient research is necessary to understand the ecology of each species -- sufficient to the extent necessary that parameter values selected are a useful approximation of species-specific behavior or characteristics. Parameters include breeding and population patch size, both of which are likely available in the literature. A third parameter is the designation of an ecological neighborhood. This value is used to determine habitat suitability in the vicinity of a focal pixel. Neighborhood effects are associated with the perceptual range of the species and edge effects. Both processing time and model results are sensitive to this parameter. CorridorDesigner documentation states, "Because little data is available on how edge effects and perceptual range affect species perceptions of habitat suitability, it is difficult to determine the optimal neighborhood size for every individual species. Estimates of home ranges, daily spatial requirements, and the relationship between body mass and spatial requirements may all be useful in determining an ecological neighborhood". It would be useful to identify some ecological/life history characteristic on which to base defining neighborhood size and thus this parameter. In this modeling exercise, ecological neighborhood was defined multiple ways depending on what was easily and quickly found, largely through internet searches. The last parameter is habitat patch suitability threshold. This is the threshold between suitable and unsuitable [sic] habitat. Modeling documentation should clearly describe the nexus between the threshold value and how the species responds to landscape characteristics. Specifically, derivation of

the threshold must be clearly described along with its relationship to the ecology of the species.

3. Maxent modeling
   a. The Maxent model, which delineated habitat suitability for many of the species modeled, is the foundation upon which all subsequent analyses (e.g., delineation of habitat cores and connectivity) rest. To validate this and subsequent analyses, the Maxent modeling process must be thoroughly described and evaluated. It would also be useful to undertake diagnostic analyses to fully understand the extent to which results from subsequent modeling processes are sensitive to changes in the results of the Maxent model.
4. Full participation of staff vs. Lack of knowledge
   a. FWP staff and external cooperators, especially biologists and others in the field, have a wealth of knowledge about the species they manage and the landscapes in which they work. Participation to share this knowledge to inform this project was a limitation. In general, biologists lacked the knowledge about broad scale connectivity to assess fully the products derived in the core and connectivity modeling process -- and perhaps in other processes. In many cases the species and knowledge specific to connectivity just simply does not exist. However, constructive criticism, of final products must be available to define and execute analyses and evaluate the results of those analyses. In most cases feedback was unavailable to inform this project. A handful of staff participated fully and consistently in the formal data review process. In the future, better participation and even distribution of workload for specific species may facilitate more effective production of data and products.
5. A clearer understanding of avian and bat movement and migration behaviors
   a. Some observers of the modeling process might wonder if mapping connectivity for flying animals is important or useful. The point being that these species can overcome terrestrially-based obstacles to movement and therefore are not limited in movement capability. This may be true, however the degree to which it is true remains an open question. Further research should be undertaken to more fully understand how flying animals interact with the landscape over which they fly. This includes landscape features they avoid (e.g., power lines, mountain ranges, or large water bodies) and prefer (e.g., areas similar to habitat, passes). Additionally, it is important to better understand directional movement as influenced by these features and associated with migration into, within, and out of the state.
6. Terrestrial vs. avian species
   a. With regard to terrestrial vs. avian species, it may be beneficial to use the terms permeability and movement, respectively. That is, in the classic connectivity model,

the idea is to understand how permeable the landscape may be for a given species. In other words, to describe the relative costs associated with landscape characteristics as an individual moves across that landscape. This classic model seems to not work so well when avian species are the focus of analysis. The idea of permeability doesn't seem to make as much sense, as it the medium of movement -- the air -- may not be heterogeneous to the point it matters in terms of connectivity. To get at this issue, we contacted Dan Casey of the American Bird Conservancy to inquire about whether birds "care" what they fly over. If the answer was yes, then perhaps the classic connectivity construct of developing a cost surface and analyzing movement in conjunction with that might make sense. If the answer was no, that meant another construct would be needed to describe the concept of avian connectivity, and more importantly, call into question the current approach this project took with avian species. Furthermore, scale of movement may influence behavior. When species are migrating some clearly fly over an inhospitable landscape, for example passerines that fly over the ocean. At that level of movement it may not matter what avian species fly over. However, when migrating species are looking for a place to land, the landscape characteristics over which they are flying may be more important. At this scale of interaction individuals (or flocks) may be selecting for specific characteristics and avoiding others in the attempt to find stop-over or breeding habitat. Lastly, there is inter-patch movement. Again, it is unclear whether it matters what individuals fly over as they move from one patch of habitat to another.

i. Unfortunately, the answers we got from Dan -- or more specifically several of his colleagues -- weren't so clear and scale of interaction may have something to do with that. Some of the feedback is summarized below:
    1. Birds tend to survive better over dark areas when migrating nocturnally
    2. Migrating birds tend to follow geographic features such as river valleys, cliffs, mountains and other landmarks
    3. Migrating birds tend to follow habitat features, for example ecotones between forested and non-forested lands
    4. Raptors may key in on landscapes in which they can find prey species
    5. More important issues may center on fragmentation, patch size, and patch configuration
    6. Some landscape features seem to be barriers, such as mountain ranges perpendicular to flight, towers, and wind turbines

7. For patch-to-patch movement, gap distance may be more important that what the "gap" consists of

b. This connectivity modeling effort is biased towards bird species -- which, arguably, is a bad idea (see previous points). Consideration should be given to analytically identifying as small set of focal species for which connectivity is an important life history characteristic. Typically, these species are sensitive to landscape conditions, rely on successful natal dispersal to ensure genetic diversity, operate in some type of metapopulation dynamic, etc. In these cases landscape permeability is an important metric to identify and understand. In the Washington state analysis only two birds were selected as focal species (out of a total of 16 species) -- sharp-tailed and greater sage grouse -- both of which are ground dwellers. This project likely should have more carefully identified the suite of focal species to be analyzed. Favor should have been given to species for which the chosen analytical methods were most appropriate and more clearly in line with achieving project goals -- creation of a terrestrial-based connectivity map.

7. More clearly defining habitat regions (in terms of patch clustering or abilities to bridge habitat gaps)
   a. Further research is necessary to better understand the degree to which multiple adjacent patches are perceived (or not-perceived) as a single continuous patch of habitat. For flying species, patches of core habitat were buffered by 2.5 miles. The assumption was that patches within 5 miles of each other were functionally connected. This seems reasonable, but should be researched on a species-by-species basis to ensure this assumption holds and doesn't not adversely affect results. Similarly, it would be important to understand how patch clustering or the ability to bridge habitat gaps affects terrestrial species in terms of how connected or disconnected the landscape might be. Perception distance is an important species-specific characteristic related to this issue. The CorridorDesigner model contains a parameter associated with a species' ecological neighborhood (see item 1a). For the most part, our modeling effort translated this parameter as a species' perception distance. However, perception distance (or range) is only part of the conceptual construct this parameter was meant to represent in CorridorDesigner. See Tool Help associated with the Create habitat patch map module of CorridorDesigner for a more thorough discussion of this parameter.
8. Developing a better understanding of how species use the landscape for movement when it does not constitute what is typically defined as habitat for that species.
   a. Many recognize that animals may use portions of the landscape for movement that they wouldn't use for other life history needs. It would be useful to more fully understand the extent to which this is true and what key landscape characteristics

species are cluing into as they move across portions of the landscape that are otherwise not considered habitat.

9. Incorporate the use of GPS technology and genetics
    a. GPS technology can provide a minute-by-minute account of an individual's whereabouts. Data acquired at such a resolution (or some other short time interval) can provide insight regarding movement patterns and habitat affinities. Further research involving collaring individuals would greatly benefit this modeling effort in two ways. First, such information would enhance parameterization of habitat suitability models, further strengthening the basis for subsequent modeling efforts. Second, location data would help validate connectivity models.
    b. Additionally, incorporation of genetic analyses would greatly enhance understanding of similarity among populations and thus how connected/disconnected populations may be. Either way, this information can help validate connectivity models and perhaps provide evidence to help understand the strength and importance of connections between/among specific patches of core habitat (see point below).
10. Connectivity strength vs. importance
    a. It is important to understand the relationships associated with connectivity strength and importance, as both are factors that contribute to the quality/utility of a connection or linkage zone. Strength is a measure of habitat quality or frequency of use of a given connection or linkage zone. Whereas importance is a measure of the contribution that connection or linkage zone makes to population viability. Movement habitat may allow individuals to disperse to distant habitat patches. Such movements may be extremely rare with many years passing between events. But despite the rarity of occurrence, such movements may be critical for maintaining genetic diversity needed for the long term survival of the species, or to facilitate recovery into habitats where the species has been extirpated. In this instance, the connection strength between patches may be quite low given the connection isn't frequently used. However, the importance of the connection is extremely high, as populations may become genetically isolated without it.
11. Potential vs. occupied habitat
    a. Clear indication should be made regarding the intent of the modeling exercise when it comes to delineation of potential versus occupied habitat. This distinction is specifically important for species that have been extirpated from large portions of their former range, though it is also important for any recolonization/range expansion process. For example, grizzly bears and black-tailed prairie dogs have occupied and could now occupy large portions of the state. From the standpoint of identifying habitat cores, should areas of high quality unoccupied habitat be

omitted from the analysis? If you ask me, I'd say no! This decision also has significant bearing on delineating connectivity. From a management and conservation standpoint, if unoccupied portions of former range are to ever be reoccupied, it would be critical to understand potential connections among occupied and unoccupied cores. Clearly, connectivity modeling can make a contribution here. However, absent cores to connect, there is no connectivity map.

12. Models vs. expert opinion
    a. Part of developing analyses for a project such as this is to define a set of analytical methods, thoroughly identify and describe the strengths/weaknesses and assumption, and stick to those methods. Methods are consistent and repeatable, and should yield consistent results given the same input data. This is how we do science. Such an approach would have been ideal for this project. However, there exists a lot of useful information that cannot be captured by or incorporated into modeling exercises. This presents a dilemma regarding how best to capture and incorporate information in a way that improves results. In this project, results of modeling exercises were adjusted by expert-opinion. Although incorporating expert feedback involves staff, fosters inclusiveness and ownership, and includes species/area-specific knowledge, all of which are arguably good things, it isn't science and may not be repeated easily or ever. Furthermore, incorporating expert opinion requires a thoughtful and thorough process to ensure feedback is accurately captured and well documented, and takes a lot of time on the part of the person providing feedback and the person collecting feedback. Whether to incorporate expert opinion as part of a scientific modeling exercise is a dicey proposition. There are many benefits and liabilities. Much thought needs to go into how to balance these two methods of acquiring and generating information (see item 3a) . Similarly, much thought needs to go into developing ways of being able to track how each method influences results, perhaps in ways that influences can be parsed from each other.
13. Use of project
    a. Scale plays an important role in this project. As we move from coarse to fine scale we need to address this point a couple of different ways. First, modeled core habitat and connectivity represents a coarse scale approach to how a species might use the landscape. That is, generalized information is analyzed to paint an abstract picture of reality. Contrast this to fine scale on-the-ground, site-specific knowledge acquired by empirically or anecdotally. Second, results of this modeling exercise are represented at a state-wide or species range scale. What happens to a species at this scale in terms of population characteristics and behaviors is likely to differ from what happens at a local scale. Third, because of the prior two points, use of

this product becomes more limited as results are viewed at a finer and finer scale. That is, interpretation and utility becomes more dependent on input and knowledge contributed by regional biologists about specific places on the landscape. In other words, although model results may well describe the generalized statewide characteristics of core habitat and connectivity they could be quite wrong for any given acre or even square mile of the landscape.

14. Identification of needs to direct research
    a. Research into the parameters needed for modeling, as mentioned in point 2 above is invaluable to these sorts of efforts. Further work to be able to clearly identify the target objective needed to improve connectivity understanding is needed. Clearly identifying the scale of needed data and how it may be used will help in developing research priorities.
15. Integration of finer scale data
    a. Use of this data, as mentioned in point 13, is dependent upon scale. However, many data sources exist that are available at the local level. Taking the opportunity to integrate data from this project into a decision making system like the Montana FWP Crucial Areas Planning System is key to determining utility and building improvements. Part of the functionality of such a tool for the on the ground users is having the ability to view or utilize all information available for a particular area. Integrating local level, finer scale data, where available, is key to the functionality of such a system.
16. Non core-based models
    a. Recent work by Carlos Carol and Dave Theobold is exploring the generation of permeability surfaces independent of the delineation of core habitat patches. This process involves the generation of a cost surface and conducting connectivity modeling against that surface using a series of randomly generated points. As cost distance models are quite influenced by the final shape of the core habitat patches, this technique holds promise to show “true” permeability in lieu of the bias of core habitat patch edge placement. This technique requires running many models and overlaying them and thus is computationally intensive.

5. Reference Information

5.1 Tables List

Table 1. Comparison of existing focal species selection approaches.
Table 2. Initial list of species used for focal species selection process.
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Figure 2. Species selection matrix headings.
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Figure 5. Example of Data Review using "Survey Monkey".
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Figure8. Baird's Sparrow core habitat, stepping stones, and the minimum number of connectivity slices needed to connect all habitat cores.
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5.2. Glossary

Circuit Theory - An approach used to estimate corridors on the landscape for individual species based on landscape features that inhibit movement. This approach is also useful for prioritizing multiple corridors for conservation.

Connectivity – A general term for the degree of movement of species and/or processes in a given area. Connectivity is commonly broken down into two types: Structural Connectivity and Functional Connectivity.

> **Structural Connectivity** – The relationship between habitat patches in terms of size, adjacency, and distance between patches. This type of connectivity is scale dependent and relates only to landscape structure.
>
> **Functional Connectivity** – The combination of structural connectivity and the behavioral responses of individual species to the landscape structure. This type of connectivity is both scale dependent and subject dependent.

Corridor – A spatially explicit area that allows for daily, seasonal, and/or dispersal movement of plant and animal species between habitats thus preserving or enhancing population stability, genetic diversity and ecological processes.

Important Wildlife Corridors – Crucial habitats that provide connectivity over different time scales (including seasonal or longer), among areas used by animal and plant species. Wildlife corridors can exist within unfragmented landscapes or join naturally or artificially fragmented habitats, and serve to maintain or increase essential genetic and demographic connection of populations (from WGA).

Focal Species – A subset of species selected to represent the connectivity needs of all native species in the area of focus. These species are chosen based on, habitat and dispersal needs, sensitivity to barriers and habitat fragmentation, ecological importance, and the degree to which their needs are threatened.

Habitat Fragmentation – Reduction of usable habitat through natural and anthropogenic (artificial) processes that split larger habitat patches into smaller ones. Natural fragmentation processes include vegetation loss due to fire, flood, high winds, and disease. Anthropogenic fragmentation processes include development (energy and housing) and the infrastructure that accompanies this development (roads, trains, and powerlines).

Habitat Patch – A contiguous area of land-cover that supports a species, or population during all or part (breeding) of its (their) life cycle.

Least-Cost Path – A common approach for estimating corridors on the landscape that is based on the cost (risk) of movement in various land-cover types for a specific species.

Linkage – Large areas of habitat connecting protected lands. This implies broader regions of connectivity than does the term “corridor” but the two terms are often used synonymously.

Matrix – The area between habitat patches through which species move. The matrix may consist of a number of different landcovers ranging from urban to agricultural to native vegetation that is not habitat for that species.

Permeability (Landscape Permeability) - The degree to which the landscape will allow wildlife movement.

Scale – The spatial and/or temporal dimension in which the species or process operates.

5.3. Acronyms

AWL – American Wildlands

CAPS – Crucial Areas Planning System

CERI – Craighead Environmental Research Institute

CFWCS - Comprehensive Fish and Wildlife Conservation Strategy

CWG – Connectivity Working Group

LLB – Large Landscape Blocks

MFWP – Montana Fish, Wildlife & Parks

MNHP – Montana Natural Heritage Program

NGO – Non-Governmental Organization

POD – Point Observation Database

SCE – Species Connectivity Expert Committee

SOC – Species of Concern

TAC – Technical Advisory Committee

WCS – Wildlife Conservation Society

WGA – Western Governors Association

5.4 Appendices

Appendix A. Committee and Group Members

Species / Connectivity Experts Committee

First Name	Last Name	Affiliation
Kurt	Alt	Montana Fish Wildlife and Parks
Vickie	Backus	Montana State University
Jon	Beckmann	Wildlife Conservation Society
Allison	Begley	Montana Fish Wildlife and Parks
Scott	Bergen	Wildlife Conservation Society
Brent	Brock	Craighead Environmental Research Institute
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Amy	Cilimburg	Montana Audubon
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Janet	Ellis	Montana Audubon
John	Ensign	Montana Fish Wildlife and Parks
Craig	Fager	Montana Fish Wildlife and Parks
Wendy	Francis	Yellowstone to Yukon Conservation Initiative
Cormack	Gates	University of Calgary
Claire	Gower	Montana Fish Wildlife and Parks
Bob	Inman	Wildlife Conservation Society
Andrew	Jakes	Montana Fish Wildlife and Parks
Kelvin	Johnson	Montana Fish Wildlife and Parks
Brent	Lonner	Montana Fish Wildlife and Parks
Bryce	Maxell	Montana Natural Heritage Program
Katie	Meiklejohn	American Wildlands
Sarah	Olimb	World Wildlife Fund
Ryan	Rauscher	Montana Fish Wildlife and Parks
Chris	Servheen	US Fish and Wildlife Service
Shawn	Stewart	Montana Fish Wildlife and Parks
Dylan	Taylor	American Wildlands
Dean	Waltee	Montana Fish Wildlife and Parks
Deborah	Wambach	Montana Department of Transportation
Michael	Whitfield	Heart of the Rockies Initiative
Catherine	Wightman	Montana Fish Wildlife and Parks
Jim	Williams	Montana Fish Wildlife and Parks

Focal Species Selection Group

First Name	Last Name	Affiliation
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Dwight	Bergeron	Montana Fish Wildlife and Parks
Vanna	Boccadori	Montana Fish Wildlife and Parks
Brent	Brock	Craighead Environmental Research Institute
Dan	Casey	American Bird Conservancy
Amy	Cilimburg	Montana Audubon
Pete	Coppolillo	Wildlife Conservation Society
Steve	Corn	Rocky Mountain Science Center
Lance	Craighead	Craighead Environmental Research Institute
Janet	Ellis	Montana Audubon
Kevin	Ellison	Wildlife Conservation Society
Craig	Fager	Montana Fish Wildlife and Parks
Vanessa	Fields	US Fish & Wildlife Service
Cormack	Gates	University of Calgary
Paul	Hendricks	Montana Natural Heritage Program
April	Johnston	American Wildlands
Stephanie	Jones	US Fish & Wildlife Service
Angela	Kociolek	Western Transportation Institute
Susan	Lenard	Montana Natural Heritage Program
Brent	Lonner	Montana Fish Wildlife and Parks
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Ryan	Rauscher	Montana Fish Wildlife and Parks
Chris	Servheen	US Fish and Wildlife Service
Jeanne	Spaur	Fort Peck Tribes
Michael	Whitfield	Heart of the Rockies Initiative
Catherine	Wightman	Montana Fish Wildlife and Parks
Jim	Williams	Montana Fish Wildlife and Parks

Connectivity Working Group (invitees; not all participated)

First Name	Last Name	Affiliation
Kurt	Alt	FWP R3
Ross	Baty	MDNRC
Kristy	Bly	World Wildlife Fund
Stephen	Carpenedo	MDEQ
Lance	Craighead	Craighead Environmental Research Institute
Molly	Cross	Wildlife Conservation Society
Windy	Davis	FWP R7
Doris	Fischer	FWP Department Management
Wendy	Francis	Yellowstone to Yukon Conservation Initiative
Cormack	Gates	University of Calgary
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Mark	Hebblewhite	University of Montana
Jeff	Herbert	FWP HQ
Janet	Hess-Herbert	FWP HQ
Matt	Jaeger	FWP R7
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Tracy	Lee	Miistakis Institute, University of Calgary
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Rick	Mace	FWP R1
Maria	Mantas	The Nature Conservancy
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Dave	Naugle	University of Montana
Robin	Russell	FWP HQ
Bob	Sanders	Ducks Unlimited
Dave	Schmetterling	FWP R2
Mike	Schwartz	USFS Rocky Mountain Research Station
Chris	Servheen	University of Montana
Gregg	Servheen	Idaho Dept of Fish and Game
Carolyn	Sime	FWP HQ
Deb	Wambach	Mt Department of Transportation
Michael	Whitfield	Heart of the Rockies

Appendix B. Montana Fish, Wildlife and Parks Connectivity Charter

VERSION: 6.0 **REVISION DATE: 2/19/2010**

Purpose of this Charter: The project charter serves the function of clearly defining a project. The reason for completing a project charter is to document the need for the project and a description of the outcome. The intentions and desired outcome(s) need to be absolutely clear so actions can be put into place to complete the project.

In this case it also serves to get buy-in from agency executives and managers on the work being performed and the commitment to allocate the resources necessary to complete the project.

Approval of the Project Charter indicates an understanding of the purpose and content described in this deliverable. By signing this deliverable, each individual agrees work should be initiated on this project and necessary resources should be committed as described herein.

Approver Name	Title	Signature	Date
Dave Risley	FWP Fish & Wildlife Division Administrator		
Ken McDonald	Wildlife Bureau Chief		
T.O. Smith	Strategic Planning and Data Services Bureau Chief		

Project Overview

Problem Statement

The high demand for urban and natural resource development is driving the need for a tool that allows the state to be proactive in addressing potential impacts on Montana's fish and wildlife resources. Currently the state of Montana does not have comprehensive representation of important wildlife connectivity areas. Connecting habitat patches, large areas of natural vegetation, and other landscape components will facilitate species movement for foraging, dispersing, breeding, migration, escape, and range shifts. Allowing for movement will maintain or increase diversity, ecosystem processes and genetic variation resulting in wildlife populations that are resilient to disturbance and climate change. Understanding the types and location of connectivity habitat in Montana will allow management agencies to better assess potential development impacts, and ensure the persistence of healthy wildlife populations.

Project Description

The primary goal of the project is the development of wildlife connectivity GIS layer(s) for Montana. These layers will be developed for selected focal species, with significant input from experts both within and outside of Montana Fish, Wildlife & Parks. The resulting layer(s) will be integrated into the Crucial Areas and Connectivity Assessment. In doing so, this project will support Montana Fish, Wildlife & Parks mission and provide an update to the agency's Comprehensive Fish and Wildlife Conservation Strategy (Montana's State Wildlife Action Plan).

Project Goals and Objectives

- Develop wildlife connectivity layers that identify wildlife corridors and linkage zones for selected focal species.
- Identify effective scales for source data and display purposes.
- Create definitions for four (4) categories for ranking connectivity and rank each linkage.
- Create management recommendations for corridors and linkage zones as appropriate.
- Create a communication and implementation plan.
- Document the processes and methodologies used in the creation of the connectivity layers.
- Integrate resulting connectivity layer(s) into Montana Crucial Areas Mapping Service.

Project Scope

The scope defines project limits and identifies the products and/or services delivered by the project. The scope establishes the boundaries of the project and should describe products and/or services that are outside the project scope NOTE: Use this section to ensure project does not experience "scope creep".

Project Includes:

- Continued refinement of product requirements.
- Determining the options for creation of connectivity layers.
- Evaluation of options for creation of connectivity layers including spatial and temporal scales to be represented.
- Documentation of process steps needed to complete connectivity layer development.
- Development of the connectivity layer(s) which can be used to proactively and efficiently address development and conservation proposals.
- Determination of how layers will be combined and ranked.
- Integration of data layers into the Crucial Areas Mapping Service to expose data layers for use by FWP and external constituents.
- Evaluation of data needs and future improvements, including recommendations to FWP staff and external partners on contributing future data.
- Project updates to grantors, FWP staff and external partners.
- Recommendations for future refinements to the connectivity layers.
- Recommendations for field data collection protocol/procedures.

Project Excludes:

- Site level information at a scale finer than the source data used for the Crucial Areas Assessment (currently a section).

- The analysis of how climate change may alter connectivity will not be conducted in this project. The expectation is that this product will facilitate that analysis in the future.
- A complete analysis of threats and conservation potential on and adjacent to identified corridors.

Critical Success Factors

- Commitment by FWP Division leadership to complete the project.
- A commitment by the Wildlife Bureau for necessary staff resources during the project.
- A commitment by external species level experts for data input, review and evaluation of the product.
- Establishment of a communication avenue for input from identified users, which may or may not influence the final product.
- Adherence to the project plan, with proposed changes going through a change review process.
- A clear plan for communication internally and externally.
- A final ranked connectivity layer that has been evaluated and approved by experts that represent a cross-section of potential users.
- Documentation that gives transparency to the mapping process (assumptions made, data quality, etc) and clearly describes the caveats associated with map use.
- Documentation of data needs that can be used to direct future data collection efforts and to improve future connectivity layers.
- Adequate tracking of budget and clear communication to funders.

Assumptions

Describe any project assumptions related to business, technology, resources, scope, expectations or schedules.

- Method used to derive connectivity will be driven by the data available.
- Agency administrators will support and prioritize staff involvement with timely feedback for necessary review of products. Some of the needs/desires of the product will be speculated in order to condense the final information into a manageable format.
- Many process related assumptions will be required in order to complete this project and will be dependent on available data and methods used. All assumptions will be clearly documented.
- Adequate network storage space will be available to accommodate data generated.
- Product reviews with staff will follow the protocol of the Crucial Areas Assessment and be done using remote technology.

- The resulting product will be created by FWP for the use of conserving terrestrial wildlife habitat.

Constraints

Describe any project constraints being imposed in areas such as schedule, budget, resources, products to be reused, technology to be employed, products to be acquired and interfaces to other products. List the project constraints based on the current knowledge today.

- Time - work needs to be completed during the grant timelines
- Data availability
- Data quality
- Personnel resources may be limited
- Budget: Funds may not be able to include all functionality desired

Project Authority and Milestones

Funding Authority

- Identify the funding amount and source of authorization and method of finance (i.e., capital budget, rider authority, appropriated receipts) approved for the project. Wildlife Conservation Society – $50,000 - Staff Resources
- National Fish and Wildlife Foundation – $25,100 - Operations
    - Connectivity Expertise -$6300
    - Data Development, supplies, materials - $5500
    - Development and documentation of layers - $1000
    - Connectivity Specialist Travel - $6000
    - Connectivity Working Group ground travel $5400
    - Connectivity Working Group meeting expenses $900

Project Oversight Authority

Describe management control over the project. Describe external oversight bodies and relevant policies that affect the agency governance structure, project management office, and/or vendor management office.

Dave Risley, Fish and Wildlife Division Administrator, will have project oversight responsibility. T.O. Smith, Strategic Planning and Data Services Bureau Chief, and Ken McDonald, Wildlife Bureau Chief, will provide Fish and Wildlife Administrator appropriate level of information to oversee the project. Janet Hess-Herbert is contract liaison and is responsible for all contract deliverables.

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Major Project Milestones

List the project's major milestones and deliverables and the planned completion dates for delivery. This list should reflect products and/or services delivered to the end user as well as the delivery of key project management or other project-related work products.

Milestone/Deliverable	Planned Completion Date
WCS - Add Project to Conservation Registry	2/5/2010
Prioritized focal species list	4/1/2010
WCS Project Report 6 Months	7/15/2010
WCS Project Final Report	1/15/2011
Aquatic layer & Intermountain West portion Terrestrial Layers completed	12/31/2010
Terrestrial Connectivity Data Layer(s) – Draft for Review	10/31/2010
Terrestrial Connectivity Data Layer(s) - Final	12/31/2010
Integration into MT FWP Decision Support System	1/31/2011
Complete management recommendations	1/31/2011

Roles and Responsibilities

Role	Responsibility/Roles/Time Commitment
Technical Advisory Committee Regional and HQ Wildlife Bureau Staff	Provide guidance on overall strategic direction. Members will meet three times as a group in March, July, and December, either in person or through web conferencing. Members may also be called upon for short meetings as specific advisory needs arise. Total estimated time investment is 40 hours/member over the life of the project.

Species Experts FWP Wildlife Bureau staff and external partners	Provide expertise on focal species' habitat and connectivity needs. Review and provide feedback on habitat and connectivity maps. Experts will meet as a group for approximately four hours in March and again in December either in person or through web conferencing. Experts will also review maps with technical staff in small groups or individually. Total estimated time investment is a maximum of 40 hours/staff member over the life of the project.
Project Staff FWP Data Services Staff	Management, technical development and project reporting will be the responsibilities of Data Services Section Staff.

Appendix C. SPECIES PRIORITY LIST

Preliminary Focal Species Mapping Order for the Montana Connectivity Project

Mapping order was obtained through the following steps: Threats and umbrella scores for each species were obtained from experts before and during the Connectivity Mapping meeting. The threats and umbrella scores were added to get a total score for each species. These total scores were then averaged across all experts. Species were placed in order of their average total scores. All species listed as falling under the umbrella of a higher scoring species were moved to the bottom of the list where they occur in order of their average total scores. Harlequin duck was replaced with Trumpeter swan because they utilize similar habitats and more information is available for the latter species. The final step was to move two species (wolverine and black bear) to the top of the list because current, range-wide linkage maps have been made for these species. This order is preliminary as data availability may dictate that a species be replaced by a surrogate or mapped at a future time when more information is available. The table below lists for each focal species: mapping order, general habitat types used by a species, the types of connectivity needed for species persistence, threats faced, other species that may benefit by conserving connectivity for this species, and connectivity data/information that is known to be available for this species in Montana.

Species	Order	General Occupancy Habitat	Connectivity Types	Threats	May be Umbrella for:	Habitat/Linkage Data Available
Wolverine	1	High elevation forest	Long term (genetic), Range expansion/shift	Threats are valley bottom development (residential, transportation) and are imminent for some populations.	Canada Lynx, Fisher, Grizzly Bear, Mountain Lion, Black Bear, Elk, Mule Deer, Moose, Wolf, Bighorn Sheep, Hoary Marmot, Ptarmigan.	Range-wide circuit models in progress by Wildlife Conservation Society, available by the end of July. Range wide genetic connectivity maps by US Forest Service. Expert opinion data compiled for W. MT by American Wildlands (AWL).

Black Bear	2	Forest and woodlands	Within season, Seasonal, Long term	Threats are residential development and transportation infrastructure and are not severe or imminent.	Grizzly bear, Wolf, Mountain Lion	Linkage model available based on genetic similarity and LCP for W MT developed by US Forest Service. Statewide model available soon. Expert opinion data compiled for W. MT by AWL
Greater Sage Grouse	3	Sage Steppe	Within season, seasonal	Threats are development (oil and gas, wind, and residential) and are imminent in most populations.	Sage thrasher, Sage sparrow, Brewer's Sparrow, Sharp-tailed grouse, Pygmy rabbit	Core habitat and lek areas mapped by MFWP.
Mountain Plover	4	Short grasslands	Seasonal	Threats are habitat loss and are severe and imminent.	Prairie Dog, longspurs (with mixed grass)	Habitat data available (Maxent or ReGAP models) from MTNHP.
Baird's Sparrow	5	Mixed Grasslands	Seasonal	Threats are agriculture, energy development and transportation infrastructure and are severe and imminent.	Sprague's Pipit, longspurs(with short grass)	Habitat data available (Maxent or ReGAP models).
Ferruginous Hawk	6	Shrub steppe	Seasonal	Threats are development (housing, energy, transportation, and agriculture) amd are severe for some populations in the state.	Swainson's hawk, Rough-legged hawk	Habitat data available (Maxent or ReGAP models).

Clark's Nutcracker	7	Conifer Forests	Seasonal	Threats are climate change and loss of whitebark pine amd are severe and imminent.	Grizzly Bear, Pinyon Jay, Brown Creeper	Habitat data available (Maxent or ReGAP models)
Long-billed Curlew	8	Short and Mixed Grasslands	Seasonal	Threats are agriculture, energy development and transportation infrastructure and are severe and imminent.	Grasshopper Sparrow, Bobolink	Habitat data available (Maxent or ReGAP models). Radiolocation data available for Phillips County
Piping Plover	9	Prairie lakes and rivers	Seasonal	Threats are stream flow maintainence and loss of gravel bars and are severe and imminent.		Habitat data available (Maxent or ReGAP models)
Northern Leopard Frog	10	Prairie wetlands	Within season, seasonal	Threats are small remaining populations in areas of near extirpation in western MT and in eastern MT grazing impacts to emergent vegetation and water quality. Threats are imminent for some populations.	Great Plains Toad, Black Tern, Northern Pintail	Habitat data available (Maxent or ReGAP models)

Pronghorn	11	Sage Steppe and grasslands	Daily, Within season, Seasonal	Threats are energy development, residential development, transportation infrastructure, and fencing and are imminent for some populations.	Mule Deer, Elk, Pygmy Rabbit, Swift Fox, Sage Grouse, TBEB	Migration study in progress for northeastern Montana. Seasonal ranges delineated statewide. Expert opinion data compiled for W. MT. Some migration information compiled.
Hoary Bat	12	Woody wetlands and riparian	Daily, Within season, Seasonal	Threats are energy development (wind), and climate change and are not imminent but may have statewide impacts. Disease is also a concern.		Habitat data available (Maxent or ReGAP models).
Trumpeter Swan	13	Wetlands	Seasonal	Threats include climate change and wind development and are imminent for some populations.	Common loon, American white pelican, Tundra swan, Northern pintail, Harlequin duck, Franklin's gull, Common tern, Black tern	Habitat data available (Maxent or ReGAP models). Nesting site locations available.
Black Rosy Finch	14	Alpine tundra	Seasonal, Range expansion/shift	Threats are habitat loss due to climate change and are severe and imminent.	White-tailed Ptarmigan	Habitat data available (Maxent or ReGAP models)

Townsend's Bat	15	Caves and riparian areas	Daily, Within Season, Seasonal	Threats are habitat loss due to climate change and are not imminent but may have statewide impacts. Disease is also a concern.	Fringed Myotis, Spotted Bat, Pallid Bat	Habitat data available (Maxent or ReGAP models)
Cassin's Finch	16	Dry coniferous forests	Seasonal	Threats are logging and residential development and are not imminent but could be severe statewide.		Habitat data available (Maxent or ReGAP models)
Rufous Hummingbird	17	Woody wetlands and riparian. Riparian migrators	Seasonal	Threats are loss of riparian habitat and area not imminent but could be severe statewide.	Black Swift, Lewis's woodpecker, veery and ovenbird	Habitat data available (Maxent or ReGAP models).
Wilson's Phalarope	18	Herbaceous wetlands	Seasonal	Threats are wetland loss due to climate change and dewatering. Threats are not imminent but could be severe statewide.	Long-billed Dowitcher	Habitat data available (Maxent or ReGAP models).
Beaver	19	Woody wetlands and riparian	Long term, Range expansion/shift	Threats are residential development and climate change. Threats are not imminent statewide and are not severe in eastern MT but may be severe in western MT.	Western toad; N. Leopard frog; Snapping turtle, Hoary bat, fringed myotis, terrestrial gartersnake, Northern River Otter, other riverine riparian	Habitat data available (Maxent or ReGAP models).

Snapping Turtle	20	Small prairie rivers	Within season, seasonal	Threats are not severe or imminent due to altered hydrology from climate change or agricultural use.		Habitat data available (Maxent or ReGAP models).
Idaho Giant Salamander	21	Moist coniferous forests and cold mountain streams	Range expansion/shift	Threats are canopy removal and alteration of hydrology and are not imminent for some populations.		Habitat data available (Maxent or ReGAP models).
Spiny Softshell Turtle	22	Large prairie rivers	Seasonal	Threats are severe and imminent due to population isolation by dams, altered hydrology in small streams, and habitat loss to shorline riprap.		Telemetry data available
Pika	23	Talus slopes	Range expansion/shift	Threats area not imminent but may have statewide impacts due to climate change.	Hoary Marmot	Habitat data available (Maxent or ReGAP models).
Prairie Rattlesnake	24	Upland grasslands and herbaceous	Seasonal	Threats are human persecution near developed areas and transportation infrastructure.Threats area not imminent but could have statewide impacts.		Habitat data available (Maxent or ReGAP models).

Plains Gartersnake	25	Upland grasslands and herbaceous	Seasonal	Threats are transportation infrastructure and are not severe or imminent .		Habitat data available (Maxent or ReGAP models).
Terrestrial Gartersnake	26	Forests and woodlands	Seasonal	Threats are transportation infrastructure and are not severe or imminent .		Habitat data available (Maxent or ReGAP models).
Connectivity for the species below may be covered by mapping connectivity for one or more of the species above.						
Grizzly Bear	27	Forests and grasslands	Daily, Within season, Seasonal, Long Term, Range shift/expansion	Threats are energy development, residential development, and transportation infrastructure. Threats are imminent for some populations.	Black Bear, Wolf, Mountain Lion, Lynx, Wolverine, Elk, Moose, Marmot	Rangewide LCP linkage maps have been developed. Range wide expert opinion data is compiled . Linkages based on empirical data developed for northern Montana. Expert opinion linkage information compiled for W. MT.
Elk	28	Forests and grasslands	Seasonal	Threats are energy development, residential development and transportation infrastructure. Threats are not imminent but may have impacts statewide.	Mule Deer, Black Bear, Mountain Lion, Wolf, Grizzly Bear	Seasonal ranges are delineated. Expert opinion data is compiled for W. MT. Some migration information is compiled and linkages are mapped for small portions of the state.

Pygmy Rabbit	29	Sagebrush	Long term, Range expansion/shift	Threats are habitat loss from energy development, residential development, and climate change. Threats are not imminent but may have statewide.	Sage grouse, Sage thrasher, Sage sparrow, Brewer's Sparrow, Sharp-tailed grouse	Habitat data available (Maxent or ReGAP models).
Mule Deer	30	Upland grasslands and herbaceous	Seasonal	Threats are not imminent but may have statewide impacts due to energy development, residential development, and transportation infrastructure.	Elk, Pronghorn, Mountain Lion, Wolf, Swift Fox	Seasonal ranges are delineated. Expert opinion data is compiled for W. MT. Some migration information is compiled
Great Plains Toad	31	Great plains floodplains	Within season, seasonal	Threats are reduced breeding habitat due to sodbusting and altered disturbances (loss of flood regimes and bison wallows). Threats are imminent and severe.		Habitat data available (Maxent or ReGAP models).
Swift Fox	32	Upland grasslands and herbaceous	Within season, Long term	Threats are loss of habitat from agriculture and transportation infrastructure. Threats are not imminent but may have statewide impacts.	Pronghorn, Mule Deer, Black-tailed Prairie Dog, TBEB	Habitat data available (Maxent or ReGAP models).

Canada Lynx	33	High elevation Forest	Long term, Range expansion/shift	Threats are logging and residential development and are not imminent but could have statewide impacts.	Fisher, Wolverine, Grizzly Bear, Black Bear, Wolf	Habitat models in progress. Expert opinion data is compiled for W. MT. General linkages delineated by USFS.
Black-tailed Prairie Dog	34	Short Grasslands	Long term	Threats are agriculture and residential development. Threats are not imminent but could have statewide impacts. Disease is also a concern	Ferruginous Hawk, Mountain Plover, Swift Fox, White-tailed prairie dog	Habitat data available (Maxent or ReGAP models).
Bighorn Sheep	35	Grasslands	Daily, Within season, Seasonal, Long Term	Threats are residential development and transportation infrastructure and are not imminent but may have statewide impacts.	Mountain Lion	Habitat data available (Maxent or ReGAP models). Expert opinion data is compiled for W. MT. Some migration information is compiled.
White-tailed Prairie Dog	36	Grasslands, shrublands and steppe	Long term	Threats are transportation infrastructure and are imminent for some populations. Disease is also a concern.	Ferruginous Hawk, Mountain Plover, Swift Fox	Habitat data available (Maxent or ReGAP models).

Mountain Lion	37	Forest and woodlands	Seasonal, Long term	Threats are residential development and transportation infrastructure and are not imminent but may have statewide impacts.	Grizzly Bear, Black Bear, Wolverine, Swift Fox, Canada Lynx	Habitat data available (Maxent or ReGAP models). Dispersal study in progress. Expert opinion information is compiled for W. MT.
Fisher	38	Forest and woodlands	Range expansion/shift	Threats are not imminent but may have statewide impacts due to habitat loss from logging and residential development.	Wolverine, Canada Lynx, Grizzly Bear, Black Bear	Habitat data available (Maxent or ReGAP models).
Gray Wolf	39	Savanna and shrub steppe,forest and woodland	Seasonal, Long term	Threats are energy development, residential development, and transportation infrastructure. Threats are not imminent but may have statewide impacts.	Grizzly Bear, Wolverine, Mountain Lion	Habitat data available (Maxent or ReGAP models). Connectivity model available but dated.
North American River Otter	40	Woody wetlands and riparian, herbaceous wetlands	Seasonal	Threats are residential development and are not severe or imminent.		Habitat data available (Maxent or ReGAP models).

Western Toad	41	Western Montana pond breeders	Within season, seasonal	Threats are transportation infrastructure and are severe and imminent. Disease is also a concern.		Habitat data available (Maxent or ReGAP models).
Hoary Marmot	42	Upland grasslands and herbaceous	Alpine tundra	Threats are climate change and are imminent for some populations in the state.	pika, ptarmigan, rosy finch	Habitat data available (Maxent or ReGAP models).
Moose	43	Forest and woodlands	Seasonal, Range expansion/shift	Threats are loss of riparian vegetation from residential development and climate change. Threats are not imminent but may have statewide impacts.	Beaver	Habitat data available (Maxent or ReGAP models).
Fringed Myotis	44	Upland grasslands and herbaceous	Daily, Within season, Seasonal	Threats are not imminent but may have statewide impacts due to climate change. Disease is also a concern.		Habitat data available (Maxent or ReGAP models).
Pallid Bat	45	Savanna and shrub steppe	Withing season, Seasonal	Threats are not imminent or severe due to disease.		Habitat data available (Maxent or ReGAP models).
Spotted Bat	46	Savanna and shrub steppe	Daily, Within season, Seasonal	Threats are climate change and are not imminent or severe.		Habitat data available (Maxent or ReGAP models).

Sprague's Pipit	47	Taller grasslands and herbaceous	Seasonal	Threats are agriculture, energy development and transportation infrastructure. Threats are severe and imminent.	Baird's Sparrow, Grasshopper Sparrow, Bobolink	Habitat data available (Maxent or ReGAP models).
Grasshopper Sparrow	48	Mixed and taller grassland and herbaceous	Seasonal	Threats are agriculture, energy development and transportation infrastructure. Threats are severe and imminent.		Habitat data available (Maxent or ReGAP models).
Harlequin Duck	49	Mountain streams	Seasonal	Threats are changing stream ecology with climate change, grazing and residential development. Threats are imminent for some populations in the state.		Habitat data available (Maxent or ReGAP models).
Sharp-tailed Grouse	50	Shrub steppe	Seasonal	Threats are residential development and are not imminent but may have statewide impacts.	Greater Sage-Grouse	Habitat data available (Maxent or ReGAP models).
Brown Creeper	51	Moist conifer forest	Seasonal	Threats are logging and residential development and are not imminent but could have statewide impacts.		Habitat data available (Maxent or ReGAP models).

Sage Thrasher	52	Sage steppe	Seasonal	Threats are agriculture, grazing, energy development and residential development. Threats are severe and imminent.		Habitat data available (Maxent or ReGAP models).
White-tailed Ptarmigan	53		Seasonal, Range expansion/shift	Threats are climate change and habitat loss and are not imminent but could have statewide impacts.		Habitat data available (Maxent or ReGAP models).
McCown's Longspur	54	Short and Mixed Grasslands	Seasonal	Threats are agriculture, energy development and transportation infrastructure. Threats are imminent for some populations in the state.		Habitat data available (Maxent or ReGAP models).
Chestnut Collared Longspur	55	Short and Mixed Grasslands	Seasonal	Threats are agriculture, energy development and transportation infrastructure. Threats are severe and imminent.		Habitat data available (Maxent or ReGAP models).
Lewis's Woodpecker	56	Riparian forest	Seasonal	Threats are logging and housing development and are severe and imminent.		Habitat data available (Maxent or ReGAP models).

Black Tern	57	Herbaceous wetlands	Seasonal	Threats are agriculture (dewatering pressures),climate change and loss of wetlands. Threats are severe and imminent.		Habitat data available (Maxent or ReGAP models).
Franklin's Gull	58	Herbaceous wetlands	Seasonal	Threats are agriculture (dewatering pressures),climate change and loss of wetlands. Threats are severe and imminent.		Habitat data available (Maxent or ReGAP models).
Brewer's Sparrow	59	Sage steppe	Seasonal	Threats are agricuture, grazing, energy development, residential development, and transportation infrastructure. Threats are severe and imminent.		Habitat data available (Maxent or ReGAP models).
Black Swift	60	Woody wetlands and riparian - waterfalls	Seasonal	Threats are climate change and loss of waterfalls and are severe and imminent.		Habitat data available (Maxent or ReGAP models).
Ovenbird	61	Deciduous forest	Seasonal	Threats are grazing, housing development and human disturbance. Threats are imminent for some populations in the state.		Habitat data available (Maxent or ReGAP models).

Pinyon Jay	62	Conifer Forests	Seasonal	Threats are loss of habitat due to climate change and conifer encroachment.		Habitat data available (Maxent or ReGAP models).
Long-billed Dowitcher	63	Herbaceous wetlands	Seasonal	Threats are agriculture (dewatering pressures),climate change and loss of wetlands. Threats are not imminent but could have statewide impacts.		Habitat data available (Maxent or ReGAP models).
Common Loon	64	Herbaceous wetlands	Seasonal	Threats are residential development, human disturbance, and climate change. Threats are imminent for some populations.		Habitat data available (Maxent or ReGAP models).
Veery	65	Riparian forest	Seasonal	Threats are human disturbance and loss of riparian vegetation due to grazing, residential development and climate change. Threats are not imminent but could have statewide impacts.		Habitat data available (Maxent or ReGAP models).

Bobolink	66	Mixed Grasslands	Seasonal	Threats are imminent for some populations due to agriculture, energy development, and transportation infrastructure.		Habitat data available (Maxent or ReGAP models).
Common Tern	67	Herbaceous wetlands	Seasonal	Threats are not imminent but could have statewide impacts due to agriculture (dewatering pressures),climate change and loss of wetlands.		Habitat data available (Maxent or ReGAP models).
Northern Pintail	68	Herbaceous wetlands	Seasonal	Threats are agriculture (dewatering pressures),climate change and loss of wetlands. Threats are not imminent but may have statewide impacts.		Habitat data available (Maxent or ReGAP models).
American White Pelican	69	Herbaceous wetlands	Seasonal	Threats are agriculture (dewatering pressures),climate change and loss of wetlands. Threats are not imminent but may have statewide impacts.		Habitat data available (Maxent or ReGAP models).

Tundra Swan	70	Herbaceous wetlands	Seasonal	Threats are agriculture (dewatering pressures),climate change and loss of wetlands. Threats are not imminent but may have statewide impacts.		Habitat data available (Maxent or ReGAP models).
Rough-legged Hawk	71	Shrub steppe	Seasonal	Threats are agriculture, grazing, energy development, residential development, and transportation infrastructure. Threats are not imminent but may have statewide impacts.		Habitat data available (Maxent or ReGAP models).
Swainson's Hawk	72	Shrub steppe	Seasonal	Threats are agriculture, grazing, energy development, residential development, and transportation infrastructure. Threats are not imminent but may have statewide impacts.		Habitat data available (Maxent or ReGAP models).

Appendix D. MaxEnt Modeling Parameters

Layer Name	**Definition**
Ecoregion	Level 4 Omernick ecoregion delineations
Landcover	Montana Landcover Map
Geology	Surface geology features in 931 categories
Soil Temperature	Soil temperature and moisture regimes
Soil Types	State soil geographic data(STATSGO) soils map with 12 classes
Elevation	The National Elevation Dataset- 1/3rd arc-second 10m grid
Aspect East/West	East west component of aspect converted to continuous values
Aspect North/South	North south component of aspect converted to continuous values
Precipitation	PRISM values for average annual precipitation
Slope	Inclination of slope in degrees derived from the elevation layer
Solar Radiation - E	Index of solar radiation striking an arbitrarily oriented surface during solar noon at the equinox
Solar Radiation - SS	Index of solar radiation striking an arbitrarily oriented surface during solar noon at the summer solstice
Solar Radiation - WS	Index of solar radiation striking an arbitrarily oriented surface during solar noon at the winter solstice
Distance to stream	Euclidean distance from major streams in meters
Minimum Temperature	Estimated average minimum daily temperatures for January
Maximum Temperature	Estimated average maximum daily temperatures for July
Terrain Ruggedness	Based on the combination of slope and aspect in individual grid cells of a 30 meter National Elevation Dataset.

Appendix E. CONNECTIVITY MODELING TECHNIQUES

There are a number of approaches to modeling wildlife habitat connectivity and a variety of software tools are available to support them. Below is a brief description of these approaches. This is not intended as a thorough review of these modeling approaches, but rather as a brief thumbnail to acquaint readers with major connectivity modeling approaches and tools available to implement them. For more information, see Singleton and McRae (in press), and Aune et al. (2011).

Patch Metrics – Patch metrics provide a way to quantify and visualize the structural relationship among habitat patches. Metrics such as patch size and nearest neighbor distances are typically summarized across a watershed or landscape level and inferences can be gained about the general connectedness of a landscape. For example, landscapes containing large blocks of unfragmented habitat are likely to be more connected than landscapes that are fragmented into smaller habitat patches. Likewise, fragmented landscapes with short distances between nearest neighbors are considered more connected than fragmented landscapes with similar habitat patch sizes but with longer distances between nearest neighbors.
Patch metrics can be useful for comparing landscapes with each other or quantifying trends over time. But the emphasis is on structural connectivity and patch metrics do not provide information about the process of how animals may move from one patch to another. Therefore they are of limited value for predicting movement patterns. One of the most popular tools for calculating patch metrics is Fragstats (http://www.umass.edu/landeco/research/fragstats/fragstats.html) ((McGarigal & Marks 1995; McGarigal et al., 2002).

Graph Theory – Graph theory uses a stick and node model to quantify connectivity between patches. Patches are represented by points (nodes) and linkages (edges) are represented as lines connecting the nodes. Graph theory has a solid foundation in mathematics and can be used to quantify the degree of connectivity among patches. Priorities can be set by quantifying the number of linkages that can be removed before connectivity to a patch is lost, or how many linkages pass through a given patch and therefore, its importance for maintaining linkage across a landscape.
Because of its quantitative approach, graph theory provides a powerful tool for measuring landscape connectivity and setting conservation priorities in a somewhat spatially explicit fashion. However, it can be less intuitive than some other approaches and therefore somewhat more challenging to understand and interpret. In addition, a stick and node graphic representation of landscape connectivity is highly conceptual and provides little information about potential fine-scale routes for movement between habitat patches. Until relatively recently, graph theory for wildlife connectivity analysis was relatively inaccessible to users without programming or at least

advanced computer skills. Now users can download Funconn (Theobald 2006) which is a toolbox for ArcMap that provides a rich set of graph theory based connectivity tools.

Cost-Distance – Cost-distance analysis is one of the most popular approaches for modeling habitat connectivity. The approach is based on the assumption that the cumulative cost of moving between two points is a function of both Euclidean distance and habitat quality. For example, moving through one distance unit of poor quality habitat may impose the equivalent cost of moving five distance units through high quality habitat. The approach is implemented by creating a cost (a.k.a. resistance) surface that assigns a relative weighting to each cell in the landscape. A variety of tools can then be applied to calculate and visualize the cumulative costs incurred as animals move across the landscape. The most common are least-cost path and least-cost corridor models. Cost-distance models are relatively intuitive and reasonably well-supported by ecological theory. They also produce easy to interpret, spatially explicit, maps for visualizing likely movement paths and corridors.

Cost-distance pathways can be quantified using metrics such as "minimum cost path" and "cost to Euclidian distance ratios", and "nth best corridors". Such quantification makes it possible to interpret multiple corridors or pathways as "better or worse" but determining thresholds for functional linkages remains difficult. In theory such thresholds could be obtained by carefully scaling costs so resulting cost-distance weightings accurately reflect Euclidian distance equivalents which would facilitate generating probalistic models. But it is unlikely researchers will ever have enough data for parameterizing a model with that degree of accuracy so, in practice, cost-distance based models should be interpreted to reflect relative values.

Several toolkits are available for generating cost-distance based models. Corridor Designer (http://corridordesign.org/) has been available for several years and is useful for designing the shape and area of corridors where linkage between habitat core patches are known. More recently, Linkage Mapper (McRae and Kavanagh 2011) and Linkage Assistant were developed concurrently to support the 2010 Washington Wildlife Habitat Connectivity Working Group (WHCWG) statewide connectivity analysis and the Montana Crucial Areas Planning System connectivity mapping efforts respectively. These tools are similar in that they automate much of the process of generating corridor models between large numbers of habitat patches and combining them into a composite linkage surface.

Circuit Theory – Circuit Theory is a relatively new approach to modeling wildlife habitat connectivity. It is based on electrical theory describing the flow of electrons through electrical circuits (McRae et al. 2008). The approach is graph-based but shares some similarities with cost-distance analysis. For habitat modeling, habitat patches (nodes) are connected to a circuit as if they were positive and negative terminals on a battery. The circuit is a resistance surface of grid cells where each cell is assigned a resistance (or conductance) value to represent the amount of

impedance (or admittance) a cell will impose on the flow of electrons based on habitat quality (or other influence on movement). Once connected, a "charge" is applied to one habitat node and "electrons" flow across the resistance surface to ground at the other node. The resulting map shows the relative flow of electrons across the landscape. The maps are somewhat similar to least-cost corridor maps except circuit theory maps tend to more strongly highlight movement bottlenecks whereas least-cost corridor maps highlight likely movement routes. One particular advantage of circuit theory models is that habitat patches can be assigned different levels of charge to reflect the relative frequency or probability of animals dispersing from a given patch. For example, large patches can be assigned a higher charge to reflect a larger resident population and therefore higher number of potential dispersers.
Although circuit theory provides a more sophisticated model than cost-distance based models, the two approaches share some of same limitations. Like cost-distance models, circuit models are sensitive to scaling so the resulting values are best interpreted as relatively "better or worse" rather than absolute. Like cost-distance models, it is difficult or impossible to assign cutoff thresholds to circuit models. In fact, one approach to constraining circuit models to within "functional linkages" is to generate least-cost corridor models, slice the resulting models into n^{th} percentiles, and use an arbitrary percentile slice to clip the circuit model.

For generating circuit models, Circuitscape (McRae and Shah 2009) is available for working within an ArcGIS environment.

Individual-based Models – Individual (agent-based) models simulate behaviors of individual animals within a population. By simulating many individuals, emergent properties at a population level are predicted. These emergent properties can describe blocks of habitat cores and likely connection between them, as well as information about population growth and persistence. Agent-based models can yield more information than previously described approaches based on landscape structure because they simulate the actual processes we are interested in (e.g. dispersal, genetic exchange, etc.). However, agent-based models typically require much more detailed information than landscape structure-based approaches to properly parameterize the complex models.
HexSim (Schumaker 2011) and its precursor, PATCH, have been used for a number of years for conservation planning. Morer recently, Agent Analyst (Johnston, 2011) (http://www.institute.redlands.edu/agentanalyst/Default.aspx) has become available for assisting with developing agent-based models within the ArcGIS environment.

Network Flow Models – Network flow is the latest edition to the connectivity modeling toolkit. Network flow models are based on graph theory but with significant advances. Network flow utilizes recent advances developed for ranking websites and social networking to allow complex computations across continuous habitat gradients rather than a simpler patch-matrix framework used in tradition graph theoretic approaches. Network flow computes centrality metrics for all pair-wise node combinations. These metrics allow users to determine the relative roles of all nodes in facilitating movement across the landscape. Network flow is computationally intensive and the resulting graphics are not as spatially explicit as those provided by cost-distance or circuit theory approaches, but network flow may represent the most powerful approach for quantifying the relative strengths of all possible movement paths available at this time.

The Connectivity Analysis Toolkit (Carroll 2010) is available for applying network flow theory to connectivity modeling. The toolkit allows users to quantify and map connectivity landscapes as well as perform time series analysis allowing users to explore connectivity through time.

Appendix F. Species level supporting information

Baird's Sparrow: supporting information

Section 3 – Habitat Patch Delineation Review

- Patches were reviewed by area biologists and feedback was used to make adjustments to the patches. (Appendix B). The final layer consists of 22 patches.

Comment	Adjustment
Core habitats occur in areas with altered land cover…altered land cover should be removed. Tilled lands should be removed from all patches…reduce patch 20	Reclassified all pixels classified as agriculture in the NLCD layer to zero in the Maxent model output. Recalculated patches based on previous settings.
Expand patches 5,6,9,11,14,15,16,10,18	Did not fit with suggestions from other reviewers to remove tilled lands in fact patches 16 and 10 were lost in this process.
Include patches north of Helena where Baird's sparrow records occur in grasslands along the front.	Used location data to select patches from the original patch file (those not big enough for first cut) and added to final patches

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 22 patches.

Section 5 – Connectivity Delineation Review

Comments received from: Allison Begley
Average rank - 4 out of 5
Adjustments: no adjustments made

Section 6 – References

Casey, D. 2000. Partners in Flight Draft Bird Conservation Plan Montana. American Bird Conservancy, Kalispell, Montana. 281 pp.

Dechant, J.A., M.L. Sondreal, D.H. Johnson, L.D. Igl, C.M. Goldade, M.P. Nenneman, and B.R. Euliss. 1998(revised 2002). Effects of Management Practices on Grassland Birds: Baird's Sparrow. Northern Prairie wildlife Research Center, Jamestown, ND 19 pages.

Lane, J. 1969. Baird's sparrow. Pages 745-765 in O.L. Austin, Jr. ed. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows and allies. Dover Publications Inc. New York.

Majka, D., J. Jenness, and P. Beier. 2007. CorridorDesigner: ArcGIS tools for designing and evaluating corridors. Available at http://corridordesign.org.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABPBXA0010.aspx

Sousa, Patrick J., and W. Neil McDonal. 1983. Habitat Suitability Index Models: Baird's Sparrow. Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC. 12 pages

Section 7 – Suggestions for Improvement

None at this time.

Mapping process steps

- Habitat/Patch Maps
  - Maxent model pulled from models run by MT NHP (U:\IndSpecies\Ammo_bair\02\MaxentOutRange)
  - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = basp_rng).
  - Ran the CD patch tool with the settings listed in section 3 (file = basp_patches).
  - Calculated the area of each patch and selected the 20 largest patches (file = basp_top20_patches).
  - Extracted locations from POD for supporting information (file = basp_locations).
- Modifying Patch Maps
  - Reclassified NLCD so that croplands and hayfields = 0 and all else = 1.
  - Multiplied reclassified NLCD and final Maxent map (basp_rng) to convert all pixels of tilled land to zero. (file = basp_noag)
  - Reran patch tool with same settings as original run (file = basp_patchesNoAg)
  - Calculated area of patches and selected 20 largest patches (file = basp_top20_NoAg).
  - Pulled out two patches from all patches (basp_patchesNoAg) that intersected basp locations along the front (file = basp_patches_addBM).
  - Merged top 20 patches with the two patches along front (file = basp_patches_adjust)

Black Rosy-Finch: supporting information

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix B). The final layer consists of 20 patches.

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 20 patches.

Section 5 – Connectivity Delineation Review

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Johnson, R. E. 2002. Black Rosy-Finch (*Leucosticte atrata*). *In* The Birds of North America, No. 678 (A. Poole and F. Gill eds.). The Birds of North America, Inc., Philadelphia, PA.

Johnsgard, P. A. 1986. Birds of the Rocky Mountains with particular reference to national parks in the Northern Rocky Mountain region. Colorado Associated University Press, Boulder. xi + 504 pp.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABPBY02010.aspx

Section 7 – Suggestions for Future Improvements

- Information on area needs of this species will help improve patch delineation.

Mapping process steps

1. Habitat/Patch Maps
   - Maxent model pulled from models run by MT NHP (U:\IndSpecies\Leuc_atra\01\MaxentOutRange). The model was based on only four locations but compares well to gap model. Copied to W (file= Leuc_atra_maxent.img)
   - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = brfinch_rng)
   - Found no little information on species area requirements, used the following settings for patch tool
     - Window -3 pixel rectangular window
     - Breeding patch – 0
     - Population patch – 259 ha (roughly the area of one section)
   - Calculated the area of each patch and selected the 20 largest patches (file = blrf_top20_patches).
   - Extracted locations from POD for supporting information (file = blrf_locations).

Black-tailed Prairie Dog

Section 3 – Patch Delineation Review

- Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix B). The final layer consists of 20 patches.

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 20 patches.

Section 5 – Connectivity Delineation Review

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Boyce, Mark S., Pierre R. Vernier, Scott E. Nielsen, Fiona K.A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling. 157: 281-300.

Harrell, D., and L. Marks. 2009. Habitat selection and changes in the white-tailed and black-tailed prairie dog population within the northern Bighorn Basin, Wyoming, Technical Note 431. U.S. Department of the Interior. Bureau of Land Management, Cody Field Office, Wyoming. BLM/WY/ST-09/031+1110. 16 pp.

Hof, John et al. 2002. Optimizing habitat location for black-tailed prairie dogs in southwestern South Dakota. Ecological Modelling. 147:11-21.

Jachowski, David S. et al. 2008. Implications of black-tailed prairie dog spatial dynamics to black-footed ferrets. Natural Areas Journal. 28:14-25.

Montana Field Guide: http://fieldguide.mt.gov/detail_AMAFB06010.aspx

Section 7 – Suggestions for Future Improvements
None at this time.

Cassin's Finch

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix B).

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 25 patches.

Section 5 – Connectivity Delineation Review
Comments received from: Undocumented
Average rank - 0 out of 5
Adjustments: no adjustments made

Section 6 – References

Hahn, T.P. 1996. Cassin's Finch (*Carpodacus cassinii*). *In* The Birds of North America, No. 240 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABPBY04030.aspx

Section 7 – Suggestions for Future Improvements
None at this time.

Mapping process steps

- Habitat/Patch Maps
    - Maxent model pulled from models run by MT NHP (U:\IndSpecies\Carp_cass\01\MaxentOutRange).
    - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = cafi_rng).
    - Ran the CD patch tool with four different times with the settings shown in the table below. Three of the runs resulted in one very large patch with smaller patches within. The final run gave multiple patches and was used for review. (file =cafi_patches4).

Run No	**Threshold**	**Window**	**Breeding Patch**	**Population Patch**
1 (file = cafi_patches)	11 (balance training omission, predicted area, threshold value)	3 pixel rectangular	25	259
2 (file = cafi_patches2)	11	3 pixel rectangular	25	100
3 (file = cafi_patches3)	11	2 pixel rectangular	25	100
4 (file = cafi_patches4)	34 (maximize sensitivity plus specificity)	3 pixel rectangular	25	100

    - Calculated the area of each patch and selected the 25 largest patches (file = cafi_top25_patches).
    - Extracted locations from POD for supporting information (file = cafi_locations).

Clark's Nutcracker

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments (Appendix B).

Comment	Adjustment
Why is there a habitat gap in Lee Metcalf Wilderness	Filled that gap. This area also contained an observational record which substantiated filling the modeled gap.

Comments received from: Bryce Maxell, Claire Gower, Allison Begley, and Shawn T. Stewart
Average rank - 4.25 out of 5
Although a question was also raised about a gap in the Absarokas near Livingston, there was no compelling reason to fill this gap. First there are no occurrence records in that gap, and second, this area is not a donut hole like the Lee Metcalf example. Rather this a large area not wholly surrounded by habitat.
The final layer consists of 21 patches, though one patch is an infill patch.

Section 5 – Connectivity Delineation Review

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Tomback, D. F. 1998. Clark's Nutcracker (*Nucifraga columbiana*). In A. Poole and F. Gill, editors. The Birds of North America, No. 331. The Academy of Natural Sciences, Philadelphia, and The American Ornithologist's Union, Washington, DC. 23 pp.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABPAV08010.aspx

Section 7 – Suggestions for Future Improvements

- Habitat suitability models might be improved by using landcover information that differentiates coniferous species (currently not available statewide).
- An understanding of factors that influence species movement (i.e. wind, landscape features) and factors that act as barriers would allow us to better examine linkages between habitat patches.

Mapping process steps

- Habitat/Patch Maps
    - Maxent model pulled from models run for Upper Clark Fork Terrestrial Assessment. (copied to W:\FWAssessment\Connectivity\Connectivity_Analysis\ClarksNutcracker\Layers)
    - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = clnu_rng).
    - Ran the CD patch tool with the settings listed in section 3 (file = clnu_patches).

- Calculated the area of each patch and selected the 20 largest patches (file = clnu_top20_patches).
- Extracted locations from POD for supporting information (file = clnu_locations).

Ferruginous Hawk

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 20 patches.

Section 5 – Connectivity Delineation Review

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Dechant, J.A., M.L. Sondreal, D.H. Johnson, L.D. Igl, C.M. Goldade, A. L. Zimmerman, and B.R. Euliss. 1998(revised 2002). Effects of Management Practices on Grassland Birds: Ferruginous Hawk. Northern Prairie wildlife Research Center, Jamestown, ND 23 pages.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNKC19120.aspx

Section 7 – Suggestions for Future Improvements

- Habitat suitability models might be improved by using landcover information that differentiates tall sagebrush from short sagebrush areas (currently not available statewide).
- An understanding of factors that influence species movement (i.e. wind, landscape features) and factors that act as barriers would allow us to better examine linkages between habitat patches.

Mapping process steps

- Habitat/Patch Maps
  - Maxent model pulled from models run by MT NHP (U:\IndSpecies\Bute_rega\02\MaxentOutRange)
  - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = feha_rng*).
  - Ran the CD patch tool with the settings listed in section 3 (file = feha_patches).
  - Calculated the area of each patch and selected the 20 largest patches (file = feha_top20_patches).

    - Pulled location from U:\IndSpecies\Bute_rega\02\PythonOut for supporting information (file = feha_locations).
- Generating Preliminary Linkage Maps
    - Buffer patches by 5 miles
    - Convert buffers to raster and run Region Group to assign contiguous regions to the same region ID
    - Assign region group IDs to original habitat patch map using Spatial Join
    - Split regions into separate shapefiles using Split by Attributes (available in corridor project toolbox)

    NOTE: the following 5 steps are automated using Create Corridor Raster
    - Generate cost surface by:
        i. Inverting the habitat quality map
        ii. Create mountainous layer by calculating terrain ruggedness index for DEM and reclassifying into 2 natural breaks. Remove pixels that are not contiguous with Omernick3 mountain ecoregions.
        iii. Multiply areas of inverted habitat quality layer that intersect mountainous areas by 0.5.
    - Generate cost-distance surfaces for each input source layer.
    - Generate corridor raster for each source layer pair specified in a custom text file.
    - Use Cell Statistics to calculate 'MINIMUM' for all corridor rasters
    - Divide combined raster into 5% slices using Slice
    - Truncate sliced raster to using appropriate cutoff

This model used fewer variables thus was more diffuse (generalized the landscape more). Patches developed with the same window and patch sizes were very large and close together.

Greater Sage-Grouse

Section 5 – Connectivity Delineation Review

Comment	Adjustment
I think the circuitscape path is the best, and my rating above is based on that one only. The other approaches are assuming we know too much.	None
Nothing is shown relative to sage grouse areas in Meagher & Park Counties and the surrounding areas. Granted sage grouse in Meagher and northern Park County are pretty much an island to themselves. Perhaps the focus is strictly on core habitat within the state. Although, how important is maintaining the widest distribution of sage grouse and sage grouse habitat as possible to the conservation of the	

species.	
I am commenting on least cost paths. The circuitscape pathways look better to me.	

Comments received from: Kurt Alt, Andrew Jakes, J. Kelvin, Drew Henry, Adam Grove, Jay Newell, Shawn Stewart

Average rank - 3.5 out of 5

Section 6 – References

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNLC12010.aspx

Section 7 – Suggestions for Future Improvements:

- Genetic analysis of feathers from lekking sites is being conducted that will allow researchers to determine the degree of genetic interchange between leks within Montana and Canada. Krissy Bush – University of Idaho
- Additional information on sage grouse movement behavior and specific barriers to that movement would improve connectivity layer precision.
- Movement data from radio-marked grouse can inform and improve connectivity analysis.

Mapping process steps

1. Habitat/Patch Maps
    - Maxent model obtained from work previously done and exported to the connectivity analysis folder (file = grsg).
    - Core habitats also obtained from work previously done and exported (file = SageGrouseCoreAreas).
2. Connectivity Maps
    - Corridor designer
        - Patches were split out from one multi-polygonal shapefile to single polygon shapefiles, identified by number (files in W:\FWAssessment\Connectivity\Connectivity_Analysis\SGrouse\CorridorDesigner\Inputs).
        - Patches selected for pairwise analysis based on their location and proximity to other patches. The patches in the southwestern portion of the range were connected to each other but not to other patches in the range. These populations in the SW are considered disconnected from the other MT pops and connecting them created some unrealistic corridors i.e. going across the beartooth mtns. (These files and the files listed below are in W:\FWAssessment\Connectivity\Connectivity_Analysis\SGrouse\CorridorDesigner\Output).
        - Ran corridor analysis using maxent model with a threshold of 8 and all other settings (breeding patch , pop patch) set to 0 per instructions in the tool information.
        - Visual examination of output suggested that the two smallest slices (0.1% and 1.0%) should be used. Merged all 0.1% pairwise slices and merged all 1.0% slices. Dissolved each of these to remove overlapping boundaries (files = CDTenthPercentCorridors, CDOnePctCorridors).
        - Merged tenth percent and one percent corridors (file = CDCorridors)

- Merged and dissolved all 5 percent corridors to provide boundary for circuitscape models (file = All5pctcorridors_Dissolve).
- Circuitscape
    - Used polygon centroid tool to developed focal nodes for the sage grouse patches. One node fell outside of the polygon (in a fold – technically the center of the polygon). It was to an area within the polygon boundary. (file = SgrouseNodes*).
    - Selected nodes to best represent a clump of node in a region (file = SgrouseNodesSelect*). Exported text file to use for cscape input.
    - Due to memory errors resampled the maxent model to 270m pixels and clipped to area within the corridor designer 5 percent corridors (file = grsg_In5p*).
    - Ran all to one in cscape, using 4 neighbors between the southwestern nodes and again between the nodes in the central part of the distribution. Did not use logistic output setting (files = cir5pcent, cir5psw** . Used raster package in R to calculate percentiles for each data set (see tables below) and reclassified so that 0 to 75% = 1, 75 to 80% = 2, 80 to 85% = 3, 85 to 90% = 4, 90 to 95% = 5, 95 to 100% = 6. (files = centpct, swpct**). This was then grouped into 3 classes for review(see above).

Central Region

Quantile	Value
75%	0.2017510
80%	0.2366280
85%	0.2853052
90%	0.3522588
95%	0.4523974

Southwest Region

Quantile	Value
75%	0.0011410
80%	0.0036850
85%	0.0086898
90%	0.0171542
95%	0.0334132

    - Used mosaic tool to combine the two data sets (file = cirbypct)

Long-billed Curlew

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
Reviewers didn't like the resulting map for a number of reasons.	Do over. Posted two new patch maps to the data reviewer. See second and third effort above. Chose to model connectivity with patches from the second effort as per reviewer comments. Patches from the second effort were larger in extent than the

first effort, but smaller in extent than the third effort -- a compromise as it were.

Comments received from: Kurt Alt, Andrew Jakes, Keith Aune, Jay Newell, Claire Gower, Allison Begley, Sarah Olimb, Kristi DuBois, Ryan Rauscher, Jim Roscoe, Gael Bissell and Shawn T. Stewart
Average rank (first effort) - 2.9 out of 5
The final layer consists of 20 patches.

Section 5 – Connectivity Delineation

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Dugger, B. D., and K. M. Dugger. 2002. Long-billed Curlew (*Numenius americanus*). *In* The Birds of North America, No. 628 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNNF07070.aspx

http://www.npwrc.usgs.gov/resource/literatr/grasbird/lbcu/lbcu.htm

http://www.jstor.org/pss/3536905 -- Space Use and Diet of Territorial Long-Billed Curlews (Numenius americanus) during the Non-Breeding Season

Mark A. Colwell, Ryan L. Mathis, Linda W. Leeman and Thomas S. Leeman; *Northwestern Naturalist*, Vol. 83, No. 2 (Autumn, 2002), pp. 47-56 (article consists of 10 pages) Published by: Society for Northwestern Vertebrate Biology

Stable URL: http://www.jstor.org/stable/3536905 During 2-hr focal observations, sizes of home range (1.3 to 7.5 ha) and total distances moved (1.1 to 2.8 km) differed among curlews.

Section 7 – Suggestions for Future Improvements

- Habitat suitability models might be improved by using land cover information that differentiates grasslands by height (short, mixed, tall).
- An understanding of factors that influence species movement (i.e. wind, landscape features) and factors that act as barriers would allow us to better examine linkages between habitat patches.

Mapping process steps

- Habitat/Patch Maps
    - Maxent model pulled from models run for Upper Clark Fork Terrestrial Assessment. (copied to W:\FWAssessment\Connectivity\Connectivity_Analysis\LBCurlew\Layers).
    - Converted model to integer values ranging from 0-100 species range is statewide so did not need to clip (file = lbcu_x100).
    - Ran the CD patch tool with the settings listed in section 3 (file = lbcu_patches).
    - Calculated the area of each patch and selected the 20 largest patches (file = lbcu_top20_patches).
    - Extracted locations from POD for supporting information (file = lbcu_locations).

Mountain Plover

Section 3 – Patch Delineation Review

- Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Action
Eliminate patches 1,2,3,4,8,10,11	Patches eliminated
Reduce 7,9,12,13,17	Reran maxent model with a threshold of 10 rather than 3 and replaced with the largest 15 patches that fell within the original patches.
Patch 7 should be reduced to areas within the Little Beaver watershed.	Clipped patch to Valley County , erased Valley CO from patch(to retain patch portion in Phillips CO)then intersected Valley Co patch with Little Beaver watershed.
Add patches above Tiber reservoir	Used different max model and patch map and pulled patch above Tiber
Add patches in Carter and Custer counties	Used different max model and pulled all patches in these two counties. Sorted these by size and chose the 15 largest patches.

Comments received from: Undocumented
Average rank - Undocumented
Final patch layer has 40 patch polygons.

Section 5 – Connectivity Delineation

Comment	Adjustment

Makes sense with linkages and stepping stones are included.	None

Comments received from: Allison Begley

Average rank - 4 out of 5

Section 6 – References

Dechant, J.A., M.L. Sondreal, D.H. Johnson, L.D. Igl, C. M. Goldade, M.P. Nenneman, and B.R. Euliss. 1998(revised 2002). Effects of management practices on grassland birds: Mountain Plover. Northern Prairie Wildlife Research Center, Jamestown, ND. 15 pages.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNNB03100.aspx

Section 7 – Suggestions for Future Improvements

- Habitat suitability models might be improved by using landcover information that differentiates short grass prairie from other grasslands (currently not available statewide).
- An understanding of factors that influence species movement (i.e. wind, landscape features) and factors that act as barriers would allow us to examine linkages between habitat patches.

Mapping process steps

- Habitat/Patch Maps
    - Maxent model pulled from models run by MT NHP (U:\IndSpecies\Char_mont\02\MaxentOutRange)
    - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = mtpl_rng)
    - Ran the CD patch tool with the settings listed in section 3 (file = mopl_patches).
    - Calculated the area of each patch and selected the 20 largest patches (file = mopl_top20_patches).
    - Extracted locations from POD for supporting information (file = mopl_locations).
- Patch modification
    - Selected patches from patch layer (mopl_top20_patches) that did not need to be adjusted and saved as new layer (mopl_patches_retain)
    - To reduce patches the patch tool was rerun with a threshold of 10. The result was more patches and smaller patches. From that run all patches that intersected the original patches 7, 9, 12, 13, and 17 were selected (file = mopl_reduced_patches, over 3000 records).
    - Clipped Valley County from the reduced version Patch 7 for further adjustment (see below).
        i. Pulled Little Beaver from 5th code HUC layer
        ii. Intersected Little Beaver HUC with Valley County portion of patch 7 (file = mopl_LittleBeav_ValleyCo),
    - Erased Valley County from Patch 7 (mopl_reduced_patches_NoValleyCo).
    - Calculated area and selected the 15 largest patches (file = mopl_reduced_final).

    - To add patches above tiber reservoir and in Carter and Custer counties
        i. The original Maxent model did not have patches in the areas suggested so a different Maxent model run was used because it had broader results. Model was

pulled from U:\Output\HomeDesktop\sppout\Mountain_Plover.asc. This model was run with fewer variables and thus gave a broader distribution.

ii. Converted model to integer values ranging from 0-100 and clipped to the species ranges(file = mtpl2_rng)

iii. Ran the CD patch tool with the settings listed in section 3 (file = mopl2_patches).

iv. Selected a large patch above Tiber reservoir and exported (file = mopl_patch_add_Tiber).

v. Selected all patches in Carter and Custer Counties calculate area and select the 15 largest patches (file = mopl2_InCarterCuster).

vi. The patches in Carter and Custer Counties were reviewed by Ryan Rauscher and he recommended they all be retained.

- Merged the following to get final patch file (mopl_adjust_final) which has 40 patches:
  i. mopl_patches_retain
  ii. mopl_LittleBeav_ValleyCo
  iii. mopl_reduced_final
  iv. mopl_patch_add_Tiber
  v. mopl2_InCarterCuster

Northern Leopard Frog

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 1 multi-part patch.

Section 5 – Connectivity Delineation

Comment	Adjustment
Looks like there are a variety of areas that have locations known but are not adequate patches - ie. poor overlap between predicted and known.	None

Comments received from: Allison Begley
Average rank - 2 out of 5

Section 6 – References

Hendricks, Paul., 1999, Amphibian and reptile surveys on Montana refuges: 1998-1999. December 1999.

Maxell, B. A., J. K. Werner, P. Hendricks, and D. L. Flath. 2003. Herpetology in Montana: a history, status summary, checklists, dichotomous keys, accounts for native, potentially native, and exotic species, and indexed bibliography. Northwest Fauna Number 5. 138 p.

Maxell, Bryce A., 2000, Management of Montana's amphibians: A Review of factors that may present a risk to population viability and accounts on the identification, distribution, taxonomy, habitat use, natural history and the status and conservation of individual species. Contract No. 43-0343-0-0224. September 20, 2000.

Montana Field Guide: http://fieldguide.mt.gov/detail_AAABH01170.aspx

Section 7 – Suggestions for Future Improvement

- Finer scale habitat data and map outputs would facilitate mapping specific linkages for this species.

Mapping process steps

- Due to the scale of movement for this species we chose to address habitat and connectivity within sections.
- Used 2009 NHD high resolution flowlines (file = NHD_Flowline) and selected Ftype = streamriver. This removed artificial paths which includes the center lines of large streams.(file names = NHD_Flowline, NHD_Flowline_NotArtificial).
- Used wetlands layer from Crucial Areas analysis (file = Wetlands_from_CACA). Selected all wetlands within 300m of NHD_Flowline_NotArtificial. (did this by HUC to keep ArcMap from crashing).
- Added major streams layer and selected all wetlands within 300m of streams to capture the wetlands along major streams. Did an additional selection to remove duplicates from the previous step.
- Merged all wetlands within 300m of streams (file = NLeopardFrogWetlands) to compile all together for state
- Used the Near function to generate a table with a record of each unique combination of wetlands within 300 meters of one another.
- Each wetland received a score that indicated the number of wetlands within 300 meter of it. It also received a point if it fell within 30 meters of a stream/river as identified in NHD.
- Each wetland was assigned to the section that its centroid fell within.
- All wetland scores were summed for each section
- All Sections with scores > 10 were considered patch/connectivity habitat. Final file = NLeopardFrog_Patches.

Piping Plover

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
Streams in NE Montana are shown as habitat but for which there are no breeding records.	None -- Seems to me it isn't worth eliminating any areas. It looks like eastern MT riparian areas are habitat for this species and whether this habitat is occupied doesn't take away from its potential to be occupied. Seems like we should accommodate the potential for outliers as was done for the Pondera Co. patch.

Comments received from: Claire Gower and Bryce Maxell
Average rank - 4 out of 5
Of interesting note, many occurrences and some portions of habitat patches lie in\under Fort Peck Lake.
The final layer consists of 20 patches.

Section 5 – Connectivity Delineation

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Haig, S.M. 1992. Piping Plover (Charadrius melodus). In A. Poole, P. Stettenheim, and F. Gill, editors, The Birds of North America, No. 2. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, DC. 18 pp.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNNB03070.aspx

U.S. Fish and Wildlife Service. 2010. Online informational search on Piping Plover in Montana. http://www.fws.gov/mountain-prairie/species/birds/pipingplover/Piping_Plover_Q&A_Sept5.htm

Section 7 – Suggestions for Future Improvements

Inputs or actions we have noticed or that have been suggested by reviewers that could improve the patch and connectivity delineations for this species.

Mapping process steps

1. Habitat/Patch Maps

- Talked with Bryce RE: are the maxent models sufficient and which (his or Scott's) seems to be the best representation. He chose his model because it seems to better express the lack of good habitat below Ft Peck dam. (Model used from U:\IndSpecies\Char_melo\01\MaxentOutRange)
- Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = pipl_rng*)
- Ran the CD patch tool with the settings listed in section 3 (file = pipl_patches).
- Calculated the area of each patch and selected the 20 largest patches (file = pipl_top20_patches).
- Extracted locations from POD for supporting information (file = pipl_breedingLocs).

2. Generating Preliminary Linkage Maps
    - Buffer patches by 5 miles
    - Convert buffers to raster and run Region Group to assign contiguous regions to the same region ID
    - Assign region group IDs to original habitat patch map using Spatial Join
    - Split regions into separate shapefiles using Split by Attributes (available in corridor project toolbox)

    NOTE: the following 5 steps are automated using Create Corridor Raster
    - Generate cost surface by:
        i. Inverting the habitat quality map
        ii. Create mountainous layer by calculating terrain ruggedness index for DEM and reclassifying into 2 natural breaks. Remove pixels that are not contiguous with Omernick3 mountain ecoregions.
        iii. Multiply areas of inverted habitat quality layer that intersect mountainous areas by 0.5.
    - Generate cost-distance surfaces for each input source layer.
    - Generate corridor raster for each source layer pair specified in a custom text file.
    - Use Cell Statistics to calculate 'MINIMUM' for all corridor rasters
    - Divide combined raster into 5% slices using Slice
    - Truncate sliced raster to using appropriate cutoff

Pygmy Rabbit

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
Remove patches 1-15 and 19	Removed these patches
Eliminate "arm" in patch 20 that extends towards patch 19	Edited patch 20 by splitting the polygon just east of Buster Brown Rd. - line was drawn perpendicular to this point. The

	"arm" polygon was deleted.
Reduce area west of Wisdom\Big Hole River in patch 20	Selected a point midway between Pintler and Plimpton Cks drew line 130 degrees to north side. Selected a point midway between Big Lake and Miner Cks drew line 90 degrees to the north side. Selected the polygon just created and deleted it.
Too much grassland on east face of Tendoy Mts	None - The identified patches in this area align well with the land cover in the land cover map.
Some areas could be described as connectivity habitat	These patches were deleted.

Comments received from: Bryce Maxell, Claire Gower, Jim Roscoe, Ryan Rauscher, and Lauri Hanauska-Brown
Average rank - 3.75 out of 5
Given the average rank is below 4 out of 5, it may be worth remodeling habitat or patches or both for this species. It seems reviewers have some level of discomfort with these results. This either means the model is right and we have to rethink what we know about this species OR the model is wrong and we need to rethink what parameters are used as model inputs. Ad hoc adjustments (such as the patch edits indicated above) are likely not the long-term solution to doing the best job of representing occupied or potential habitat given the modeling context adopted for this project.
The final layer consists of 4 patches.
The adjusted map strands six occurrence points that were previously in identified patches. Five of these points are in a clump north of Alder Gulch in Madison Co (in what was patch 13).

Section 5 – Connectivity Delineation

Comment	Adjustment
Good job on this but one concern is over buffering with Idaho	None

Comments received from: Keith Aune
Average rank - 5 out of 5
Adjustments: no adjustments made

Section 6 – References

Katzner, T.E. and K. L. Parker. 1997. Vegetative characteristics and size of home ranges used by pygmy rabbits (*Brachylagus idahoensis*) during winter. Journal of Mammalogy 78(4): 1063-1072.
Montana Field Guide: http://fieldguide.mt.gov/detail_AMAEB04010.aspx

Rauscher, Ryan. 1997. Status and distribution of the pygmy rabbit in Montana. Montana Department of Fish, Wildlife & Parks, non-game program. Unpublished report, 19 pp plus appendices.

Section 7 – Suggestions for Future Improvements

- Finer scale data is needed to better reflect the small area needs of this species.
- A better understanding of the area needed for persistence of Pygmy rabbit populations would improve patch delineation.
- An understanding of factors that influence species movement (i.e. wind, landscape features) and factors that act as barriers would allow us to examine linkages between habitat patches.

Mapping process steps

- Habitat/Patch Maps
    - Maxent model pulled from models run by MT NHP (U:\IndSpecies\Brach_idah\01\MaxentOutRange)
    - Converted model to integer values ranging from 0-100 and clipped to the species ranges (file = pyra_rng)
    - Ran the CD patch tool with the settings listed in section 3 (file = pyra_patches).
    - Used FLU agriculture layer to remove tilled lands from patches (pyra_patches_noag)
    - Calculated the area of each patch and selected the 20 largest patches (file = pyra_top20_patches).
    - Extracted locations from POD for supporting information (file = pyra_locations).

Rufous Hummingbird

Section 3 – Patch Delineation Review

- Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
Given the point data, patches seem to extend well east of known locations	None. Patches lie within the range map. The Maxent model uses habitat characteristics associated with known points to make determinations about habitat characteristics in general. The model determined areas that could serve as habitat beyond the distribution of known points.

Comments received from: Allison Begley
Average rank - 2 out of 5
The final layer consists of 20 patches.

Revised patches posted to the Data Reviewer represent the original 20 patches combined into Regions -- groups of patches that are within 5 miles of each other. The 20 patches are now combined into 8 Regions.

Section 5 – Connectivity Delineation

Comments received from: Undocumented

Average rank - 0 out of 5

Section 6 – References

Eberhard, JR and PW Ewals. 1994. Food availability, intrusion pressure and territory size: an experiments study of Anna's hummingbirds (*Calypte anna*). Behavioral Ecology and Sociobiology. 34: 11-18.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNUC51020.aspx
http://www.natureserve.org/explorer/servlet/NatureServe?searchName=Selasphorus rufus (See Ecology and Life History tab)

Google search: Rufous hummingbird dispersal distance:
http://www.learner.org/jnorth/tm/humm/ExpertAnswer09.html

Google search: Rufous hummingbird dispersal distance:
http://www.learner.org/jnorth/tm/humm/ExpertAnswer09.html

From: California

Q. Where do the rufous hummingbirds which show up at my house on the far northern coast of California in mid to late February overwinter? How many miles do they travel during each day of their migration?

A: See this map for their winter range. The daily distance depends on a lot of variables, but probably averages about 25 miles per day.

Section 7 – Suggestions for Future Improvements

Need to find an authoritative source (or sources) for rufous hummingbird to inform parameterization of the CorridorDesigner model.

Mapping process steps

Methods used to create input\output data:

- Created maxent grid using asciigrid command in ArcGrid; multiplied grid by 1000 to rescale values from 0-.999 to 0-999.xxx; integerized grid; extracted by mask the maxent model using the species range map.
- Patches were created using CorridorDesigner - Moving window was defined as Circle using Map units (meters).
- Calculated area field (in sq m); sorted by area in descending order; selected the top 20 records.

- **Note:** patches extend beyond the extent of the input data set (in this case the Maxent model grid limited to the species range). Thus, it is necessary to clip the patches generated by CorridorDesigner to the state boundary.

Swift fox

Section 3 – Patch Delineation Review

Comment	Adjustment
Representation of habitat based on WWF data seems good -- R. Rauscher stated, "VUVE3 most accurately represents swift fox habitat in my mind. The other two vastly overestimate the amount of suitable habitat."	None - see above
Overestimate of habitat	Increased threshold value to 100, approx. 10% of the input values.
Re: new Maxent Model -- R. Rauscher stated, "It is the most accurate in my mind of suitable swift fox habitat north of the Missouri River even though it over-represents south Phillips County. The other model (the pdf) perhaps more accurately represents those areas south of the Missouri River and east of the Musselshell River."	None to date.
Many areas are over represented and some are missing.	
Missing some suitable habitat and over-representation of some patches.	
I think the map is going in the right direction, but needs to be ground-truthed.	
Some areas included are too rough or contain too much cover to be considered core swift fox habitat. Expansion of some existed delineations and the additions of others should be considered.	

Comments received from: Ryan Rauscher, Dean Waltee, Brian Giddings
Average rank - 2.5 out of 5 (only 2 of 3 people provided a rank)
The final layer consists of 20 patches.

Section 5 – Connectivity Delineation

Comment	Adjustment
Some areas are over represented and some important areas are	None

underrepresented.	

Comments received from: Ryan Rauscher
Average rank - 2 out of 5

Section 6 – References

Ausband, David and Axel Moehrenschlager. 2009. Long-range juvenile dispersal and its implication for conservation of reintroduced swift fox Vulpes velox populations in the USA and Canada. Oryx. 43:73-77.

Dark-Smiley, Darby N. and Douglas A. Keinath. 2003. Species assessment for swift fox (Vulpes velox) in Wyoming. US Department of the Interior, Bureau of Land Management, Wyoming State Office, Cheyenne, Wyoming. December 2003. pp. 51.

Montana Field Guide: http://fieldguide.mt.gov/detail_AMAJA03030.aspx

Section 7 – Suggestions for Future Improvements

None at this time.

Mapping process steps

Methods used to create input\output data:

- Created maxent grid using asciigrid command in ArcGrid; multiplied grid by 1000 to rescale values from 0-.999 to 0-999.xxx; integerized grid; extracted by mask the maxent model using the species range map.
- Patches were created using CorridorDesigner - Moving window was defined as Circle using Map units (meters).
- Calculated area field (in sq m); sorted by area in descending order; selected the top 20 records.
- The WWF model was scaled from 0-255 unlike the Maxent model. To normalize these data all values were divided by 255. The resulting map was multiplied by 100 and intergerized.
- The same model threshold (59) was applied to this data set when parameterizing the patch model.
- Although the WWF data looks to provide a good representation of potential habitat for swift fox in Montana, ultimately we decided not to use data from the model due to issues regarding scaling and output values.
- **Note:** patches extend beyond the extent of the input data set (in this case the Maxent model grid limited to the species range). Thus, it is necessary to clip the patches generated by CorridorDesigner to the state boundary.

Townsend's Big-eared Bat

Section 3 – Patch Delineation Review

- Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
Relationship to caves and patch are unclear to me.	None.
They generally look OK, though we may not have enough data on this species to fully understand what they need.	
This is substantially different (i.e more extensive) than the Hoary Bat model. Lots of area covered...	

Comments received from: Keith Aune, Allison Begley, Kristi DuBois
Average rank - 3.33 out of 5
The final layer consists of 20 patches.
Revised patches posted to the Data Reviewer represent the original 20 patches combined into Regions -- groups of patches that are within 5 miles of each other. The 20 patches are now combined into 8 Regions.

Section 5 – Connectivity Delineation

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Gruver, JC and DA Keinath. 2003. Species assessment for Townsend's big-eared bat in Wyoming. This document is contained within the Documents folder associated with this species. USDI Bureau of Land Management, Wyoming State Office, Cheyenne, WY. p 64.

Montana Field Guide: http://fieldguide.mt.gov/detail_AMACC08010.aspx
Schmidt, CA. 2003. Conservation assessment for the Townsend's big eared bat in the Black Hills National Forest South Dakota and Wyoming. USDA Forest Service. Black Hills National Forest, Custer, South Dakota. p 27.

Section 7 – Suggestions for Future Improvements

The Gruver and Keinath document includes other parameters that could be used in this analysis: Used 7km foraging distance, 263 ha for breeding and population areas (foraging area) -- both are for lactating females, which seem to travel farther and use more area than non-lactating females or males.

Mapping process steps

Methods used to create input\output data:

- Created maxent grid using asciigrid command in ArcGrid; multiplied grid by 1000 to rescale values from 0-.999 to 0-999.xxx; integerized grid; extracted by mask the maxent model using the species range map.

- Patches were created using CorridorDesigner - Moving window was defined as Circle using Map units (meters).
- Calculated area field (in sq m); sorted by area in descending order; selected the top 20 records.
- **Note:** patches extend beyond the extent of the input data set (in this case the Maxent model grid limited to the species range). Thus, it is necessary to clip the patches generated by CorridorDesigner to the state boundary.
- **Google search: townsend's big-eared bat dispersal distance**

Trumpeter Swan

Section 3 – Patch Delineation Review

Patches were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5
The final layer consists of 14 patches.

Section 5 – Connectivity Delineation

Comment	Adjustment
None	None

Comments received from: Undocumented
Average rank - 0 out of 5

Section 6 – References

Henson, Paul and Todd Grant. 1991. The effects of human disturbance on trumpeter swan breeding behavior. Wildlife Society Bulletin. 19:248-257.

Montana Field Guide: http://fieldguide.mt.gov/detail_ABNJB02030.aspx

Olson, David, Jeff Warren, and Tom Reed. 2009. Satellite-tracking the seasonal locations of trumpeter swans Cygnus buccinator from Red Rock Lakes National Wildlife Refuge, Montana, USA. Wildfowl. 59:3-16.

Section 7 – Suggestions for Future Improvements

None at this time.

Wolverine- Data produced by WCS – no additional data at this time

Appendix G. Guild supporting information

Raptor Guild Supporting Information:
Connectivity Delineation

Connectivity results were reviewed by species experts and feedback was used to make the following adjustments:

Comments received from: Catherine Wightman (MFWP), Kristi Dubois (MFWP) and Amy Cilimburg (Montana Audubon)

- Model seems relatively weak relative to the known strength of the Rocky Mountain Front and known movement patterns in this area.
- Need to distinguish Spring from Fall movement
- Area from Big Belt Mountains to Bears Paw Mountains seems intriguing more research should look into the ability of this area to serve as a corridor

References

Brandes, D., and D.W. Ombalski. 2004. Modeling raptor migration pathways using a fluid-flow analogy. The Journal of Raptor Research. 38:195-20

Suggestions for Future Improvements

- Need a model that represents spring movement more closely tied to valley bottoms and less influenced by thermals as snow free locations to forage
- Montana Audubon has produced a good reference of identified migratory routes for both spring and fall seasons.
- Better models of thermal locations, wind direction and updraft, prevailing jet stream and other air movement parameters would improve this model.
- Use of GPS technology and data sets currently being obtained specifically for Golden Eagles could be beneficial.

Mapping process steps

A cost surface to predict areas of high wind deflection updrafts was created as follows:

1. Rank aspect layer. Aspects facing into (perpendicular to) prevailing winds get highest score. Our original model favored westerly slopes as shown in the following table.

Flat	0
N	0
NE	0
E	0
SE	0
S	0
SW	20
W	100
NW	20

2. Rescale slope 0-100 (steepest slope = 100)
3. Rescale Elevation Range (5 x 5 cell neighborhood of a 1km DEM) 0-100 (areas with highest elevation range = 100)
4. Multiply layers from steps 2-3 together, rescale to 0 - 100, and invert to create cost surface.

The “Create Corridor Raster” tool that was developed for this project was used to generate linkages.

- The cost surface extended approximately 150 miles west and 250 miles south of the Montana border.
- A corridor raster was generated between the north and south boundaries of the cost surface.
- The resulting map represents a cost surface where each location on the map represents the lowest cost-distance for between the northern and southern boundry of the analysis area (extent of the cost surface). This map was subdivided into 5% intervals.
- Linkage maps were submitted for review.

  NOTE: the following 5 steps are automated using Create Corridor Raster
  - Generate cost surface by inverting the habitat quality map
  - Generate cost-distance surfaces for each input source layer.
  - Generate corridor raster for each source layer pair specified in a custom text file.
  - Use Cell Statistics to calculate ‘MINIMUM’ for all corridor rasters
  - Divide combined raster into 5% slices using Slice
  - Truncate sliced raster to using appropriate cutoff

Additional raptor models were run using variations on the updraft scores:

- Updrafts over both east and west facing slopes

Flat	0
N	0
NE	20
E	100
SE	20
S	0
SW	20
W	100
NW	20

- Updrafts over east facing slopes

Flat	0
N	0
NE	20
E	100

SE	20
S	0
SW	0
W	0
NW	0

Shorebird Guild supporting information:

Connectivity Delineation

Connectivity results were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comments received from: Jim Hansen (MFWP) and Robert Sanders (Ducks Unlimited)

- Do not recommend using this layer yet.
- Relative rankings make sense in light of techniques used, but do not accurately reflect known or perceived travel routes
- Misinterpretation of data and perceived strength of results, is likely for non-biologists and biologists without understanding of methods and could be problematic or dangerous relative to implementation of conservation efforts

References

Bellrose, F.C. 1980. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Lincoln, Frederick C., Steven R. Peterson, and John L. Zimmerman. 1998. Migration of birds. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C. Circular 16. Jamestown, ND:Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/birds/migratio/index.htm (Version 02APR2002).

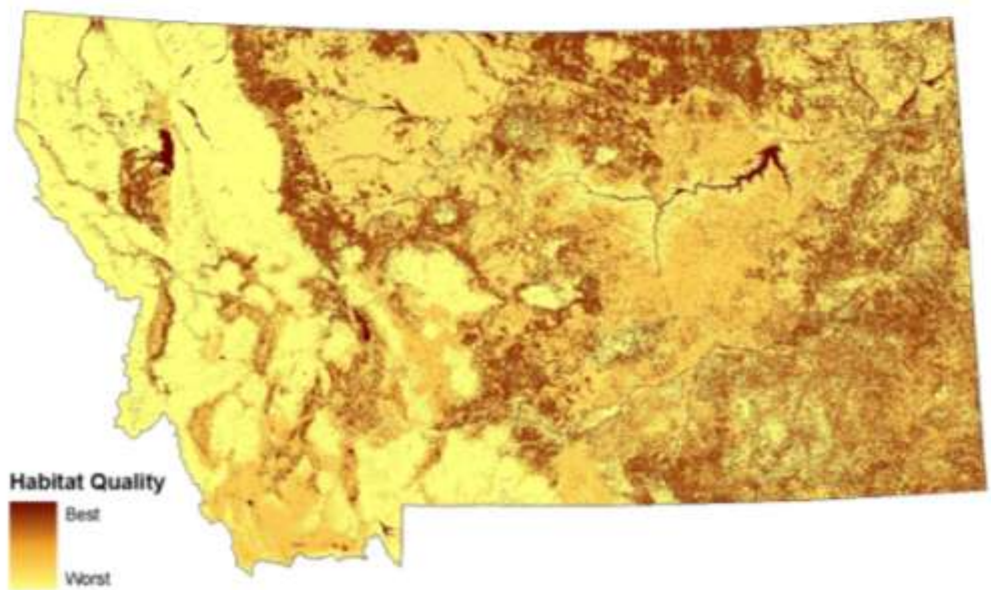
North American Waterfowl Management Plan, Plan Committee. 2004. North American Waterfowl Management Plan 2004. Strategic Guidance: Strengthening the Biological Foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales, 22 pp.

Suggestions for Future Improvements

- Combine waterbird and shorebird models
- Focus more on lacustrine habitats for these species
- Better understanding and use of banding data as it relates to movement
- Use count data to weight staging areas by relative use in a circuit theory model
- Better understanding of how elevation and landcover “guidelines” influence migration paths
- A more systematic and repeatable method for mapping major staging areas

Table X. Shorebird habitat values assigned to habitat types

Habitat Type	Habitat Value
Open Water	82.00
Pasture/Hay	26.34
Cultivated Crops	8.34
Great Plains Shrubland	18.00
Big Sagebrush Steppe	18.00
Montane Sagebrush Steppe	18.00
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	53.99
Great Plains Mixedgrass Prairie	53.99
Rocky Mountain Subalpine-Montane Mesic Meadow	18.00
Great Plains Sand Prairie	18.00
Introduced Upland Vegetation - Annual and Biennial Forbland	18.00
Recently burned grassland	18.00
Greasewood Flat	43.01
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	25.02
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	25.02
Great Plains Floodplain	73.66
Rocky Mountain Subalpine-Montane Riparian Woodland	16.68
Rocky Mountain Subalpine-Montane Riparian Shrubland	16.68
Great Plains Prairie Pothole	100.00
Alpine-Montane Wet Meadow	25.02
Great Plains Open Freshwater Depression Wetland	82.00
Emergent Marsh	25.02
Great Plains Closed Depressional Wetland	100.00
Great Plains Saline Depression Wetland	100.00
Great Plains Riparian	43.01



Waterbird habitat quality

Mapping process steps

- Compile habitat quality for guild
  a. Use species habitat association.
  b. Score each habitat type weighted by quality of association summed for all species in guild.
     i. High Quality = 3 pts; Medium Quality = 2 pts.; Low Quality = 1 pt.
     ii. Rescale scores 0-100 for each species so each species contributes equally to combined habitat scores.
     iii. Sum scores of all species within guild for each habitat type.
     iv. Invert values to create base cost layer.
  c. Reclassify elevation to apply highest cost to high elevation, and lowest cost to low elevation.
     i. Rescale elevation to 1-100
        1. Multiply base cost by rescaled elevation
  d. Assign cost within 100m buffer of tall structures (radio/cell towers, major transmission line towers, industrial wind generators, others?)
  e. Assign zero cost to staging areas regardless of result of above steps.
- Generating Preliminary Linkage Maps
  - Process internal staging areas using region groups to lump patches within 20 miles of each other into a common region.
  - Create state boundary segment patches that represent likely areas where birds will enter/exit the state (use continental migration corridors and areas of continental significance for guidance)

- Generate cost-distance model.

NOTE: the following 5 steps are automated using Create Corridor Raster

- Generate cost surface by inverting the habitat quality map
- Generate cost-distance surfaces for each input source layer.
- Generate corridor raster for each source layer pair specified in a custom text file.
- Use Cell Statistics to calculate 'MINIMUM' for all corridor rasters
- Divide combined raster into 5% slices using Slice
- Truncate sliced raster to using appropriate cutoff

Waterbird Guild Supporting Information

Connectivity Delineation

Connectivity results were reviewed by area biologists and feedback was used to make the adjustments documented in the following table:

Comments received from: Jim Hansen (MFWP) and Robert Sanders (Ducks Unlimited)

- Do not recommend using this layer yet.
- Relative rankings make sense in light of techniques used, but do not accurately reflect known or perceived travel routes
- Misinterpretation of data and perceived strength of results, is likely for non-biologists and biologists without understanding of methods and could be problematic or dangerous relative to implementation of conservation efforts

References

Bellrose, F.C. 1980. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Lincoln, Frederick C., Steven R. Peterson, and John L. Zimmerman. 1998. Migration of birds. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C. Circular 16. Jamestown, ND:Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/birds/migratio/index.htm (Version 02APR2002).

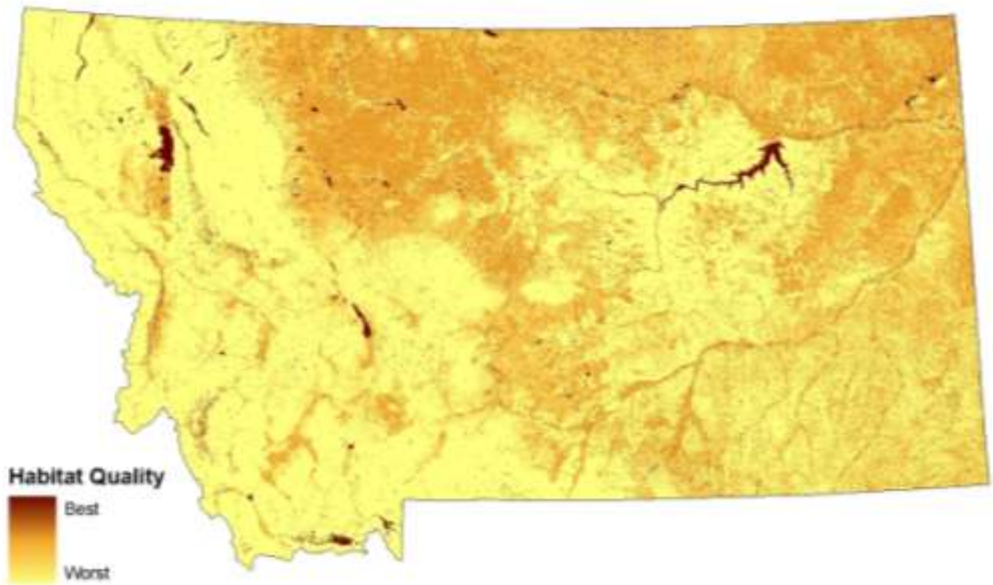
North American Waterfowl Management Plan, Plan Committee. 2004. North American Waterfowl Management Plan 2004. Strategic Guidance: Strengthening the Biological Foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales, 22 pp.

Suggestions for Future Improvements

- Potentially combine waterbird and shorebird models
- Focus more on lacustrine habitats for these species
- Better understanding and use of banding data as it relates to movement
- Use count data to weight staging areas by relative use in a circuit theory model
- Better understanding of how elevation and landcover "guidelines" influence migration paths
- A more systematic and repeatable method for mapping major staging areas

Table X. Waterbird habitat values assigned to habitat types

Habitat Type	Habitat Value
Open Water	100.00
Developed, Open Space	1.67
Pasture/Hay	13.52
Cultivated Crops	15.60
Great Plains Wooded Draw and Ravine	2.56
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	3.75
Great Plains Mixedgrass Prairie	10.06
Introduced Upland Vegetation - Annual and Biennial Forbland	5.83
Greasewood Flat	3.33
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	19.91
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	10.34
Great Plains Floodplain	18.03
Rocky Mountain Wooded Vernal Pool	15.33
Rocky Mountain Subalpine-Montane Riparian Woodland	7.77
Rocky Mountain Subalpine-Montane Riparian Shrubland	7.77
Great Plains Prairie Pothole	44.24
Alpine-Montane Wet Meadow	28.51
Great Plains Open Freshwater Depression Wetland	57.33
Emergent Marsh	98.21
Rocky Mountain Subalpine-Montane Fen	15.33
Great Plains Closed Depressional Wetland	53.82
Great Plains Saline Depression Wetland	45.49
Great Plains Riparian	21.30



Waterbird habitat quality

Mapping process steps

- Compile habitat quality for guild
    a. Use species habitat association.
    b. Score each habitat type weighted by quality of association summed for all species in guild.
        i. High Quality = 3 pts; Medium Quality = 2 pts.; Low Quality = 1 pt.
        ii. Rescale scores 0-100 for each species so each species contributes equally to combined habitat scores.
        iii. Sum scores of all species within guild for each habitat type.
        iv. Invert values to create base cost layer.
    c. Reclassify elevation to apply highest cost to high elevation, and lowest cost to low elevation.
        i. Rescale elevation to 1-100
            1. Multiply base cost by rescaled elevation
    d. Assign cost within 100m buffer of tall structures (radio/cell towers, major transmission line towers, industrial wind generators, others?)
    e. Assign zero cost to staging areas regardless of result of above steps.
- Generating Preliminary Linkage Maps
    - Process internal staging areas using region groups to lump patches within 20 miles of each other into a common region.

- Create state boundary segment patches that represent likely areas where birds will enter/exit the state (use continental migration corridors and areas of continental significance for guidance)
- Generate cost-distance model.

NOTE: the following 5 steps are automated using Create Corridor Raster

- Generate cost surface by inverting the habitat quality map
- Generate cost-distance surfaces for each input source layer.
- Generate corridor raster for each source layer pair specified in a custom text file.
- Use Cell Statistics to calculate 'MINIMUM' for all corridor rasters
- Divide combined raster into 5% slices using Slice
- Truncate sliced raster to using appropriate cutoff

Semi-Aquatic Guild Supporting Information
Connectivity Delineation

- Connectivity was determined by running connectivity models between patches in adjacent 5th code hydrologic units.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.

Connectivity results were reviewed by area biologists and feedback indicated connectivity appeared reasonable and no adjustments were made.

References

Gurnell, A. and Montgomery, D. (1998), Preface: hydrological applications of GIS. Hydrological Processes, 12: 821–822

Suggestions for Future Improvements

- Improved parameterization of all associated costs of movement
- Better parameterization for individual species to allow ability to further distinguish species specific or group specific responses to landscape factors
- Improved landcover layer modeling and riparian area delineation will aid in the identification of patches of suitable core habitat.
- Connectivity models, as described above have a exaggerated lower values along the edges of HUC boundaries where they split patches. Rerunning connectivity models with improved techniques to elimate the need for splitting on HUC would be beneficial.

Mapping Process Steps
Habitat Patch Delineation

Cost surface derivation:

This is an additive model using the following layers and associated attribute costs.
Land cover: Identified good and bad land cover classes, created a field called SA_COST, calculated values for attributes based on land cover class.

- 0 - "good" land cover classes (e.g., cottonwood, aspen, wet meadows)
- 2 - everything else
- 4 - "bad" land cover classes (e.g., cliffs, scree, bare rock, snow)

Slope: Manually classified into the 3 classes below.
- 0 - 0-15%
- 2 - 15-45%
- 4 - > 45%

Flow accumulation: Flow accumulation GRID (int_dem30_ac1) was classified values into 6 classes as defined below. During the course of modeling the explicit flow accumulation values were undocumented. However they followed an exponentially increasing cost associated with reduced flow.
- 0 (lowest cost); 1; 2; 4; 8; 16 (highest cost)

Water: Separated perennial from intermittent streams. Combined perennial streams with lake shorelines. Calculated distance to perennial streams/lakeshores independently. Classed distances for intermittent streams and perennial streams/lakeshores as below. The original plan was to undertake a similar analysis for intermittent streams and include the results in this analysis. Intermittent streams were dropped however as
Perennial streams/lakeshores: Classified values into 5 classes based on the distance from streams/lakeshores as described below.
- 0 - 0-250m
- 1 - 250-500 m
- 2 - 500-1000 m
- 4 - 1000-2000 m
- 8 - >2000 m

The above GRIDs were summed. The resulting GRID was named totalcs_nint (total cost surface with no intermittent streams). Values range from 0 to 32.
A rescaled cost surface was derived from totalcs_nint so that values ranged from 0-100. This GRID is called costsurf and is used to derive connectivity for semi-aquatics.
Connectivity delineation followed an iterative process to connect all patches in a single 5th code hydrologic unit (HUC) to all adjacent HUC's. This process was conducted for all HUC's in the state. This split on HUC boundary was done to accommodate computer processing demands.
  - Patches were intersected with HUC to obtain the unique HUC id
  - Starting with the first HUC id, all patches for source HUC were selected and combined into a region. A single patch to serve as the source patch region to run connectivity modeling.
  - Each adjacent HUC was selected in order of unique id to serve as a destination patch
  - The selected HUC patches were selected and combined into a region.

- Connectivity model output was generated from the source patch region to the adjacent HUC destination patch region.
- Corridor linkages were mapped using distance-weighted cost (cost-distance) analysis which assigns higher cost of movement through (or over) low quality habitat than for movement over the same distance through high quality habitat.
- The resulting connectivity model output is a distance weighted cost raster of relative values, where the lowest value represents the lowest cost of movement and can be interpreted as the area with the highest permeability for movement.
- All resulting connectivity rasters were mosaiced using the minimum value for each overlapping grid cell into a single statewide connectivity surface.

Note on interpretation: Connectivity models have an exaggerated minimum value where patches along single stream reaches that flow across HUC boundaries are adjacent. This adjacency shows almost no cost for movement. This should be no different than patches within a single HUC being adjacent to each other. Later modeling techniques allowed for modeling many more patches than earlier techniques. See Large Landscape Blocks and Game species modeling. This technique could be employed for this layer to improve results.

Appendix H. Large Intact Landscape Blocks Supporting Information

Table 1. Montana land cover systems retained as "native" cover (ecotypes included)

Code	Ecological System Name	General Native	Alpine Native	Grass Shrub Native	Forest Specialist Native
11	Open Water	Yes	No	No	No
21	Developed, Open Space	No	No	No	No
22	Developed, Low Intensity	No	No	No	No
23	Developed, Medium Intensity	No	No	No	No
31	Quarries, Strip Mines and Gravel Pits	No	No	No	No
81	Pasture/Hay	No	No	No	No
82	Cultivated Crops	No	No	No	No
3114	Great Plains Badlands	Yes	No	Yes	No
3129	Rocky Mountain Cliff, Canyon and Massive Bedrock	Yes	Yes	No	Yes
3130	Alpine Ice Field	Yes	Yes	No	Yes
3135	Alpine Bedrock and Scree	Yes	Yes	No	Yes
3139	Shale Badland	Yes	No	Yes	No
3142	Great Plains Cliff and Outcrop	Yes	No	No	No
3160	Active and Stabilized Dune	Yes	No	Yes	No
3173	Wyoming Basin Cliff and Canyon	Yes	No	No	No
4104	Aspen Forest and Woodland	Yes	No	No	Yes
4232	Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Yes	No	No	Yes
4233	Rocky Mountain Subalpine Woodland and Parkland	Yes	Yes	No	Yes
4234	Rocky Mountain Mesic Montane Mixed Conifer Forest	Yes	No	No	Yes
4236	Rocky Mountain Foothill Limber Pine - Juniper Woodland	Yes	No	No	Yes
4237	Rocky Mountain Lodgepole Pine Forest	Yes	No	No	Yes
4240	Rocky Mountain Ponderosa Pine Woodland and Savanna	Yes	No	No	Yes
4242	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Yes	Yes	No	Yes
4243	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	Yes	Yes	No	Yes
4266	Rocky Mountain Montane Douglas-fir Forest and Woodland	Yes	No	No	Yes
4267	Rocky Mountain Poor Site Lodgepole Pine Forest	Yes	No	No	Yes
4280	Great Plains Ponderosa Pine Woodland and Savanna	Yes	No	No	Yes
4302	Aspen and Mixed Conifer Forest	Yes	No	No	Yes
4303	Mountain Mahogany Woodland and Shrubland	Yes	No	No	Yes

4328	Great Plains Wooded Draw and Ravine	Yes	No	No	Yes
5000	Geysers and Hot Springs	Yes	No	No	No
5203	Mat Saltbush Shrubland	Yes	No	Yes	No
5207	Alpine Dwarf-Shrubland	Yes	Yes	No	Yes
5209	Low Sagebrush Shrubland	Yes	No	Yes	No
5257	Big Sagebrush Shrubland	Yes	No	Yes	No
5258	Mixed Salt Desert Scrub	Yes	No	Yes	No
5262	Great Plains Shrubland	Yes	No	Yes	No
5263	Rocky Mountain Lower Montane-Foothill Shrubland	Yes	No	Yes	Yes
5312	Rocky Mountain Montane-Foothill Deciduous Shrubland	Yes	No	Yes	Yes
5326	Rocky Mountain Subalpine Deciduous Shrubland	Yes	Yes	Yes	Yes
5426	Rocky Mountain Foothill Woodland-Steppe Transition	Yes	No	No	Yes
5454	Big Sagebrush Steppe	Yes	No	Yes	No
5455	Montane Sagebrush Steppe	Yes	No	Yes	No
7112	Rocky Mountain Lower Montane, Foothill, and Valley Grassland	Yes	No	Yes	No
7113	Rocky Mountain Subalpine-Upper Montane Grassland	Yes	Yes	Yes	Yes
7114	Great Plains Mixedgrass Prairie	Yes	No	Yes	No
7116	Alpine Fell-Field	Yes	Yes	No	Yes
7117	Alpine Turf	Yes	Yes	No	Yes
7118	Rocky Mountain Subalpine-Montane Mesic Meadow	Yes	Yes	Yes	Yes
7121	Great Plains Sand Prairie	Yes	No	Yes	No
8402	Introduced Upland Vegetation - Shrub	No	No	Yes	No
8403	Introduced Upland Vegetation - Annual and Biennial Forbland	No	No	Yes	No
8404	Introduced Upland Vegetation - Annual Grassland	No	No	Yes	No
8405	Introduced Upland Vegetation - Perennial Grassland and Forbland	No	No	Yes	No
8406	Introduced Riparian and Wetland Vegetation	No	No	Yes	No
8501	Recently burned forest	Yes	No	No	Yes
8502	Recently burned grassland	Yes	No	Yes	No
8503	Recently burned shrubland	Yes	No	Yes	No
8601	Harvested forest-tree regeneration	Yes	No	No	Yes
8602	Harvested forest-shrub regeneration	Yes	No	No	No
8603	Harvested forest-grass regeneration	Yes	No	No	No
9103	Greasewood Flat	Yes	No	Yes	No
9111	Rocky Mountain Conifer Swamp	Yes	No	No	Yes
9155	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Yes	No	No	Yes
9156	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	Yes	No	No	Yes
9159	Great Plains Floodplain	Yes	No	Yes	No
9162	Rocky Mountain Wooded Vernal Pool	Yes	No	No	Yes
9171	Rocky Mountain Subalpine-Montane Riparian Woodland	Yes	Yes	No	Yes
9187	Rocky Mountain Subalpine-Montane Riparian Shrubland	Yes	Yes	No	Yes
9203	Great Plains Prairie Pothole	Yes	No	Yes	No

9217	Alpine-Montane Wet Meadow	Yes	Yes	Yes	Yes
9218	Great Plains Open Freshwater Depression Wetland	Yes	No	Yes	No
9222	Emergent Marsh	Yes	No	Yes	No
9234	Rocky Mountain Subalpine-Montane Fen	Yes	Yes	No	Yes
9252	Great Plains Closed Depressional Wetland	Yes	No	Yes	No
9256	Great Plains Saline Depression Wetland	Yes	No	Yes	No
9326	Great Plains Riparian	Yes	No	Yes	Yes

Table 2. Inputs to the geoprocess for creation of Large Intact Landscape Blocks

Feature	Type
Incorporated Areas	Polygon
Coal Permits	Polygon
Gravel Pits	Polygon
Large Mines	Polygon
Ski Areas	Polygon
Superfund Sites	Polygon
Landfills	Polygon
Roads	Line
Railways	Line
Transmission Lines	Line
FCC Towers	Point
Wind Towers	Point
Wells	Point
Structures	Point

Appendix 1. Geoprocessing Steps

1. Create Snap Raster
    a. Inputs:
    b. Output: scratch.gdb\ snap
2. Reclass Landcover
    a. Inputs: toolData.gdb\landcover + reclass.txt file
    b. Output: output.gdb\native
3. Create Division Raster
    a. Neighborhood: 20x20 Cells, Rectangle
    b. Statistic: Sum
    c. Output: scratch.gdb\divisor
4. Remove Polygon Feature s(repeat for all polygon features)
    a. Output: output.gdb\native
5. Remove Line Features (repeat for all polyline features)

    a. Output: output.gdb\native
6. Remove Point Features (repeat for all point features)
    a. Output: output.gdb\native
7. Create Final Blocks
    a. Count Cells That Are Still Habitat
        i. Neighborhood: 20 x 20 Cells, Rectangle
        ii. Statistic: Sum
        iii. NoData: Checked
        iv. Output: scratch.gdb\movingWindowSum
    b. Divide Moving Window Sum by Divisor Raster
        i. Convert the movingWindowSum and Divisor Raster to Floating Point
        ii. Divide movingWindowSum by divisor raster
        iii. Output: output.gdb\nativeProportion
    c. Threshold The Result to Create the Blocks
        i. Output: output.gdb\nativeThreshold

Appendix I. Big Game Connectivity Delineation Review Comments

- Black Bear
  - Reviewers: Shawn Stewart (MFWP)
  - Comments:
    - This technique is too restrictive on forested habitat blocks. The percentage of 90% should be lowered for this forest generalist species.
- Canada Lynx
  - Reviewers: Shawn Stewart (MFWP)
  - Comments:
    - This technique may be reasonable for Lynx in lieu of other modeling techniques.
    - Work is being done by John Squires that will present empirical model results for the NCDE for Lynx.
- Elk
  - Reviewers: Vickie Edwards (MFWP)
  - Comments:
    - This technique misses much of the identified winter range habitat of this species. Winter range in western Montana is already relatively fragmented. As such this layer cannot accurately represent core habitats or seasonal connectivity as of yet.
    - Do not use.
- Grizzly Bear
  - Reviewers: Shawn Stewart (MFWP)
  - Comments:
    - This technique is too restrictive on forested habitat blocks. The percentage of 90% should be lowered for this forest generalist species.
    - The Interagency Grizzly Bear team, and specific biologist working on Grizzly bears should have additional comments that should be solicited.
- Moose
  - Reviewers: Shawn Stewart (MFWP)
  - Comments:
    - This technique may be reasonable for Moose in lieu of other modeling techniques.
- Mountain Lion
  - Reviewers: Shawn Stewart (MFWP), Craig Fager (MFWP), Hugh Robinson (University of Montana)
  - Comments:
    - This technique is too restrictive on forested habitat blocks. The percentage of 90% should be lowered for this forest generalist species.
    - There are many other factors that are not being considered that help define core habitats outside of forest such as topography. These need to be integrated before layer will begin to truly show Mountain Lion core habitats.

        - These results are surprisingly similar to the RSF models produced by the MFWP Mountain Lion Research project. Forest is the primary factor identified. Costs may be overstated relative to anthropogenic factors.
        - Much research exists and is being developed on this species.
- Mule Deer
    - Reviewers: Vickie Edwards (MFWP)
    - Comments:
        - This technique misses much of the identified winter range habitat of this species. Winter range in western Montana is already relatively fragmented. As such this layer cannot accurately represent core habitats or seasonal connectivity as of yet.
        - Do not use.
- Pronghorn
    - Reviewers: Andrew Jakes (University of Calgary), Jay Newell (MFWP), Kelvin Johnson (MFWP)
    - Comments:
        - This technique misses including what would be considered robust core habitats supporting good populations of animals due to the exclusion of agriculture in generating core habitats.
        - One area in the Beartooth range is wrong
        - Need to add in the areas on the National Bison Range

Appendix J. Large Landscape Block Modeling Cost Parameters

Code	Ecological System Name	General Cost	AlpineSppCost	GrassShrub Cost	Forest Specialist Cost
11	Open Water	80	75	80	75
21	Developed, Open Space	75	75	75	75
22	Developed, Low Intensity	100	100	100	100
23	Developed, Medium Intensity	100	100	100	100
31	Quarries, Strip Mines and Gravel Pits	100	100	100	100
81	Pasture/Hay	25	25	10	25
82	Cultivated Crops	50	50	25	50
3114	Great Plains Badlands	5	25	5	5
3129	Rocky Mountain Cliff, Canyon and Massive Bedrock	25	5	25	25
3130	Alpine Ice Field	25	5	25	25
3135	Alpine Bedrock and Scree	25	5	25	25
3139	Shale Badland	5	25	5	5
3142	Great Plains Cliff and Outcrop	25	25	25	25
3160	Active and Stabilized Dune	5	25	5	5
3173	Wyoming Basin Cliff and Canyon	25	25	25	25
4104	Aspen Forest and Woodland	5	5	25	5
4232	Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	5	5	50	5
4233	Rocky Mountain Subalpine Woodland and Parkland	5	5	50	5
4234	Rocky Mountain Mesic Montane Mixed Conifer Forest	5	5	50	5
4236	Rocky Mountain Foothill Limber Pine - Juniper Woodland	5	5	25	5
4237	Rocky Mountain Lodgepole Pine Forest	5	5	50	5
4240	Rocky Mountain Ponderosa Pine Woodland and Savanna	5	5	50	5
4242	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	5	5	50	5
4243	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	5	5	50	5
4266	Rocky Mountain Montane Douglas-fir Forest and Woodland	5	5	50	5
4267	Rocky Mountain Poor Site Lodgepole Pine Forest	5	5	50	5
4280	Great Plains Ponderosa Pine Woodland and Savanna	5	5	25	5
4302	Aspen and Mixed Conifer Forest	5	5	50	5
4303	Mountain Mahogany Woodland and Shrubland	5	10	5	5
4328	Great Plains Wooded Draw and Ravine	5	25	25	5
5000	Geysers and Hot Springs	25	25	25	25

5203	Mat Saltbush Shrubland	5	25	5	20
5207	Alpine Dwarf-Shrubland	5	5	5	20
5209	Low Sagebrush Shrubland	5	25	5	20
5257	Big Sagebrush Shrubland	5	25	5	20
5258	Mixed Salt Desert Scrub	5	25	5	20
5262	Great Plains Shrubland	5	25	5	20
5263	Rocky Mountain Lower Montane-Foothill Shrubland	5	10	5	20
5312	Rocky Mountain Montane-Foothill Deciduous Shrubland	5	10	5	20
5326	Rocky Mountain Subalpine Deciduous Shrubland	5	5	5	20
5426	Rocky Mountain Foothill Woodland-Steppe Transition	5	5	25	20
5454	Big Sagebrush Steppe	5	25	5	20
5455	Montane Sagebrush Steppe	5	25	5	20
7112	Rocky Mountain Lower Montane, Foothill, and Valley Grassland	5	25	5	20
7113	Rocky Mountain Subalpine-Upper Montane Grassland	5	5	5	20
7114	Great Plains Mixedgrass Prairie	5	25	5	20
7116	Alpine Fell-Field	5	5	5	20
7117	Alpine Turf	5	5	5	20
7118	Rocky Mountain Subalpine-Montane Mesic Meadow	5	5	5	20
7121	Great Plains Sand Prairie	5	25	5	20
8402	Introduced Upland Vegetation - Shrub	5	25	5	20
8403	Introduced Upland Vegetation - Annual and Biennial Forbland	5	25	5	20
8404	Introduced Upland Vegetation - Annual Grassland	5	25	5	20
8405	Introduced Upland Vegetation - Perennial Grassland and Forbland	5	25	5	20
8406	Introduced Riparian and Wetland Vegetation	5	25	5	20
8501	Recently burned forest	5	5	25	5
8502	Recently burned grassland	5	25	5	20
8503	Recently burned shrubland	5	25	5	20
8601	Harvested forest-tree regeneration	5	5	50	5
8602	Harvested forest-shrub regeneration	5	10	25	20
8603	Harvested forest-grass regeneration	5	25	5	20
9103	Greasewood Flat	5	25	5	20
9111	Rocky Mountain Conifer Swamp	5	5	50	5
9155	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	5	10	25	5
9156	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	5	10	25	5
9159	Great Plains Floodplain	5	25	5	20

9162	Rocky Mountain Wooded Vernal Pool	25	10	25	25
9171	Rocky Mountain Subalpine-Montane Riparian Woodland	5	5	50	5
9187	Rocky Mountain Subalpine-Montane Riparian Shrubland	5	5	25	5
9203	Great Plains Prairie Pothole	25	25	5	25
9217	Alpine-Montane Wet Meadow	5	5	5	20
9218	Great Plains Open Freshwater Depression Wetland	25	25	5	25
9222	Emergent Marsh	25	25	5	25
9234	Rocky Mountain Subalpine-Montane Fen	25	5	5	25
9252	Great Plains Closed Depressional Wetland	25	25	5	25
9256	Great Plains Saline Depression Wetland	25	25	5	25
9326	Great Plains Riparian	5	25	25	5

Appendix K. Large Landscape Block Model Processing Parameters

Applicable to all:

- All Core patches selected at an area of 5000 acres or greater. Except for Alpine which was 2000 acres or greater
- All core pairs analyzed at 10km buffer unless otherwise specified.
- All region pairs analyzed at 20km buffer unless otherwise specified.
- All LILB cores were simplified using Point Remove with 200m maximum distortion

All-General

- Cores – n = 780
    a. Core Generation
        i. General LILB Cores – All statewide
    b. Core Connections – n = 2011; Within 10 km
        i. Cost Layer: General
- Regions – n = 61
    a. Regions based upon combining cores with edges within 5 km
    b. Region Connections – n = 240; Within 70 km
        i. Distance based on furthest distance to connect a patch with multiple options

Alpine

- Cores – n = 93
    a. Core Generation
        i. All LILB alpine cores
    b. Core Connections –n = 195; Within 25 km (10km analysis buffer)
        i. Distance based upon visual estimation to connect core patches
        ii. Cost Layer : Alpine
- Regions – n = 22
    a. Regions based upon combining cores with edges within 15 km
    b. Region Connections n = 117 – Within 200 km (20km analysis buffer)

Grass/Shrub

- Cores – n = 512
    a. Core Generation
        i. All LILB grass/shrub cores
    b. Core Connections –n = 1348; Within 15 km (10km analysis buffer)
        i. Distance based upon visual estimation to connect core patches
        ii. Cost Layer : Grass/Shrub
- Regions – n = 53
    a. Regions based upon combining cores with edges within 10 km
    b. Region Connections – n = 323; Within 150 km (20km analysis buffer)

Forest Generalist

- Cores – n = 297
    a. Core Generation
        i. All LILB forest cores
    b. Core Connections – n = 1353; Within 25 km (10km analysis buffer)
        i. Distance based upon visual estimation to connect core patches
        ii. Cost Layer : General
- Regions – n = 15
    a. Regions based upon combining cores with edges within 15 km
    b. Region Connections – n = 40; Within 150 km (20km analysis buffer)

Forest Specialist

- Cores – n = 165
    a. Core Generation
        i. All LILB forest cores
    b. Core Connections –n = 565; Within 25 km (10km analysis buffer)
        i. Distance based upon visual estimation to connect core patches
        ii. Cost Layer : Forest Specialist
- Regions – n = 15
    a. Regions based upon combining cores with edges within 15 km
    b. Region Connections – n = 46; Within 150 km (20km analysis buffer)

Black Bear

- Cores – n = 185
    a. Core Generation
        i. All LILB forest cores
        ii. These were replaced by cores of island mtn ranges
            1. Many island polygons did not have core forest blocks
        iii. Judith/Moccasins manually added in
    b. Core Connections – n = 612; Within 25 km
        i. Distance based upon visual estimation to connect core patches
        ii. Cost Layer : Forest Spp
- Regions – n = 16
    a. Regions based upon combining cores with edges within 15 km
    b. Region Connections – n= 57; Within 150 km
        i. Distance based upon connecting island mountain ranges

Elk

- Cores – n = 365
    a. Core Generation
        i. General LILB Cores – those overlapping Distribution
    b. Core Connections – n = 796; Within 10 km
        i. Distance based upon visual estimation to connect core patches

ii. Cost Layer : General Spp

- Regions – n = 26
    a. Regions based upon combining cores with edges within 5 km
    b. Region Connections – n = 106; Within 150 km
        i. Distance based from Sweetgrass hills to CMR and RMFront

Grizzly Bear

- Cores – n = 72
    a. Core Generation
        i. Forest LILB Cores – Selected by those touching Consistently occupied habitat
    b. Core Connections – n = 258; Within 25 km
        i. Note this Core Corridor buffer is 20 km
        ii. Cost Layer : Forest Spp
- Regions – n = 6
    a. Regions based upon combining cores with edges within 10 km
    b. Region Connections – n = 8; Within 200 km
        i. Distance based on connecting the NCDE to GYA
        ii. Note this Region Corridor buffer is 40 km

Lynx

- Cores – n = 54
    a. Core Generation
        i. Forest LILB Cores – Those forest cores touching USFWS Critical Habitat
    b. Core Connections – n = 194; Within 25 km
        i. Core analysis area is 20 km buffer
        ii. Cost Layer : Forest Spp
- Regions – n = 4
    a. Regions based upon combining cores with edges within 10 km
    b. Region Connections – n = 4; Within 200 km
        i. Distance based on connecting GYA to NCDE
        ii. Note: 40 km buffer on reg analysis

Moose

- Cores – n = 166
    a. Core Generation
        i. Forest LILB Cores – Based on all forest cores, added in areas of Rubies, Sweetgrass hills and Winter Range near Dillon
    b. Core Connections – n = 571; Within 25 km
- Regions – n = 13
    a. Regions based upon combining cores with edges within 15 km
    b. Region Connections – n = 34; Within 150 km
        i. Distance based on Distance to Sweetgrass hills

Mule Deer

- Cores – n = 780
    a. Core Generation
        i. General LILB Cores – All statewide
    b. Core Connections – n = 2011; Within 10 km
- Regions – n = 61
    a. Regions based upon combining cores with edges within 5 km
    b. Region Connections – n = 240; Within 70 km
        i. Distance based on furthest distance to connect a patch with multiple options

Mountain Lion

- Cores – n = 347
    a. Core Generation
        i. Forest and General LILB Cores – Selected all Forest cores within distribution in Western MT, Selected all general cores within distribution in prairie and East of Beartooth plateau
    b. Core Connections – n = 1607; Within 25 km
- Regions – n = 9
    a. Regions based upon combining cores with edges within 15 km
    b. Region Connections – n = 20; Within 100 km
        i. Distance based on distance between most distant features

Pronghorn Antelope

- Cores – n = 510
    a. Core Generation
        i. Grass LILB Cores – All overlapping distribution as well as all other grass cores (Reservations) except those in the Flathead area
    b. Core Connections – n = 949; Within 10 km
        i. Distance based upon visual estimation to connect core patches
        ii. Cost Layer : Grass Spp
- Regions – n = 113
    a. Regions based upon combining cores with edges within 5 km
    b. Region Connections – n = 384; Within 60 km
        i. Distance based on those between grassland cores on the RMFront

Appendix L. Confidence Ratings

Species Models	Category	Results Quality	Source Data Quality	# of Reviewers	Current Understanding	Rating Consistency
Baird's Sparrow	MaxEnt/HSI Model	Medium	Medium	Unk	Medium	Medium
	Core Patches	Low	Low	4	Medium	Medium
	Connectivity Model	Low	Low	1	Low	Medium
Black Rosy-Finch	MaxEnt/HSI Model	Low - NE	Low	Unk	Low	Low - NE
	Core Patches	Low - NE	Low	0	Low	Low - NE
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Black-tailed Prairie Dog	MaxEnt/HSI Model	High	High	2	High	Medium
	Core Patches	High	Medium	2	Medium	High
	Connectivity Model	Medium	Low	2	Low	Medium
Cassin's Finch	MaxEnt/HSI Model	Low - NE	Medium	Unk	Low	Low - NE
	Core Patches	Low - NE	Low	0	Low	Low - NE
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Clark's Nutcracker	MaxEnt/HSI Model	Low	High	Unk	Medium	Medium
	Core Patches	Low	Low	4	Low	Medium
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Ferruginous Hawk	MaxEnt/HSI Model	Low	Medium	Unk	Low	Medium
	Core Patches	Low	Low	7	Low	Medium
	Connectivity Model	Low	Low	0	Low	Medium
Greater Sage-Grouse	MaxEnt/HSI Model	High	High	Unk	High	High
	Core Patches	High	High	10	Medium	High
	Connectivity Model	Medium	Low	7	Low	Medium
Long-billed Curlew	MaxEnt/HSI Model	Medium	Low	Unk	Medium	Medium
	Core Patches	Medium	Medium	13	Low	Medium
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Mountain Plover	MaxEnt/HSI Model	Medium	Medium	Unk	High	Medium
	Core Patches	Medium	Medium	5	Medium	Medium
	Connectivity Model	Medium	Low	1	Low	Medium
Northern Leopard Frog	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low	Low	3	Medium	Medium
	Connectivity Model	Low	Low	1	Medium	Medium
Piping Plover	MaxEnt/HSI Model	Low	Low	Unk	Medium	Medium
	Core Patches	Low	Low	2	Medium	Medium
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Pygmy Rabbit	MaxEnt/HSI Model	Medium	Medium	Unk	Medium	Medium
	Core Patches	Medium	Medium	5	Medium	Medium
	Connectivity Model	Medium	Low	2	Low	Medium

Rufous Hummingbird	MaxEnt/HSI Model	Low	Low	Unk	Low	Medium
	Core Patches	Low	Low	1	Low	Medium
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Swift Fox	MaxEnt/HSI Model	Medium	Low	Unk	Medium	Medium
	Core Patches	Medium	Low	6	Medium	Medium
	Connectivity Model	Low	Low	1	Low	Medium
Townsend's Big-eared Bat	MaxEnt/HSI Model	Low	Low	Unk	Medium	Medium
	Core Patches	Low	Low	3	Low	Medium
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Trumpeter Swan	MaxEnt/HSI Model	Medium	Low	Unk	Medium	Medium
	Core Patches	Medium	Low	3	Medium	Medium
	Connectivity Model	Low - NE	Low	0	Low	Low - NE
Wolverine	MaxEnt/HSI Model	Medium	High	Unk	High	High
	Core Patches	High	High	6	High	High
	Connectivity Model	Medium	Low	6	Medium	High
	NOTE: WCS layer with intial development and review occuring independent of of the MFWP connectivity project. Data above reflects MFWP review.					
Guild Models	**Category**	**Results Quality**	**Source Data Quality**	**# of Reviewers**	**Current Understanding**	**Rating Consistency**
Raptors	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	N/A	Medium	3	Low	Medium
	Connectivity Model	Low	Medium	3	Medium	Medium
Semi-aquatics	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Medium	Medium	2	Medium	Medium
	Connectivity Model	Medium	Low	2	Low	Medium
Shorebirds	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	N/A	Medium	3	Medium	High
	Connectivity Model	Low - DNU	Low	3	Medium	High
Waterbirds	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	N/A	Medium	3	Medium	High
	Connectivity Model	Low - DNU	Low	3	Medium	High
Large Landscape Block Species Group	**Category**	**Results Quality**	**Source Data Quality**	**# of Reviewers**	**Current Understanding**	**Rating Consistency**
Black Bear	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low	Medium	2	High	High
	Connectivity Model	Medium	Low	2	Medium	High
Canada Lynx	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Medium	Medium	1	Medium	High
	Connectivity Model	Medium	Medium	1	Medium	High

Elk	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - DNU	Medium	2	High	High
	Connectivity Model	Low - DNU	Medium	2	Medium	High
Grizzly Bear	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Medium	Medium	2	Medium	High
	Connectivity Model	Medium	Medium	2	Medium	High
Moose	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Medium	Medium	1	Medium	High
	Connectivity Model	Medium	Low	1	Medium	High
Mountain Lion	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Medium	Medium	3	High	Medium
	Connectivity Model	Low	Medium	3	Medium	Medium
Mule Deer	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - DNU	Medium	1	Medium	High
	Connectivity Model	Low - DNU	Low	1	Medium	High
Pronghorn	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Medium	Medium	3	Medium	Medium
	Connectivity Model	Medium	Medium	3	Medium	Medium
Large Landscape Block Ecological Systems Group	**Category**	**Results Quality**	**Source Data Quality**	**# of Reviewers**	**Current Understanding**	**Rating Consistency**
LLB All- General	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - NE	Medium	0	Medium	Low - NE
	Connectivity Model	Low - NE	Medium	0	Medium	Low - NE
LLB Alpine	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - NE	Medium	0	Medium	Low - NE
	Connectivity Model	Low - NE	Medium	0	Medium	Low - NE
LLB Grass/Shrub	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - NE	Medium	0	Medium	Low - NE
	Connectivity Model	Low - NE	Medium	0	Medium	Low - NE
LLB Forest Generalist	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - NE	Medium	0	Medium	Low - NE
	Connectivity Model	Low - NE	Medium	0	Medium	Low - NE
LLB Forest Specialist	MaxEnt/HSI Model	N/A	N/A	N/A	N/A	N/A
	Core Patches	Low - NE	Medium	0	Medium	Low - NE
	Connectivity Model	Low - NE	Medium	0	Medium	Low - NE